METAL PROGRESS

OCTOBER, 1938.

· ANNUAL · REFERENCE · ISSUE ·

· McDONALD ·

NEW HORIZONS

FOR years Surface Combustion has realized that the building of successful furnaces for Industry was more than a drawing board job . . . that old theories and practices were headed for the discard, to be replaced by newer, progressive methods of heat treating to match the progress of industrial production. . . With this realization came the definite conviction that our job was not only to fabricate the tangible elements of the furnace, but—just as important—to study, devise and develop new and better ways of heat treatment. . . The processes of Eutectrol Carburizing and Dry Cyaniding—the gas fired radiant tube and the convection furnace, are typical examples of SC developments worked out in cooperation with industry. New developments will come just as surely as industry will continue to progress.

SURFACE COMBUSTION CORPORATION . . . TOLEDO, OHIO

If you failed to receive or have mislaid your copy of this forty page booklet which illustrates and describes many types of recent industrial furnace installations—send for a free copy or ask for it at our booth in the Gas Section at the Metal Show.

SURFACE COMBUSTION

October, 1938 Volume 34, Number 4

Metal Progress

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NATIONAL METAL CONGRESS AND EXPOSITION

DETROIT OCT. 17 to 21, 1938

CONSOLIDATED PROGRAM

National Metal Congress

AMERICAN SOCIETY FOR METALS — AMERICAN WELDING SOCIETY

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

WIRE ASSOCIATION

Sunday, Oct. 16, 1938

5:00 P.M. A.W.S.; President's Reception; Book-Cadillac Hotel

Monday, Oct. 17, 1938

9:30 A.M. A.W.S.; Structural Welding; Book-Cadillac Hotel
10:00 A.M. Simultaneous Technical Sessions; Hotel Statler
10:00 A.M. A.I.M.E. (Institute of Metals) Session on Copper and Brass; Book-Cadillac Hotel
10:00 A.M. A.I.M.E. (Iron & Steel) Session on Steelmaking; Book-Cadillac Hotel
12:00 M. National Metal Exposition opens; Convention Hall
12:15 P.M. A.I.M.E. (Institute of Metals) Executive Committee Luncheon; Book-Cadillac Hotel
1:00 P.M. W.A.; Directors' Meeting, Program Committee Meeting; Detroit-Leland Hotel
2:00 P.M. Technical Session; Convention Hall
2:00 P.M. A.W.S.; Simultaneous Sessions on Production Welding and Industrial Research; Book-Cadillac Hotel
2:00 P.M. A.I.M.E. (Institute of Metals) Session on Physical Metallurgy; Book-Cadillac Hotel
2:00 P.M. A.I.M.E. (Iron & Steel) Session on Steelmaking; Book-Cadillac Hotel
2:30 P.M. W.A.; Steel Spring Wire; Detroit-Leland Hotel
2:30 P.M. W.A. and A.I.M.E.; Copper Wire; Detroit-Leland Hotel
4:30 P.M. Lecture Course, Machinability; Convention Hall
8:00 P.M. Lecture Course, Pyrometry; Convention Hall
10:30 P.M. National Metal Exposition closes

Tuesday Morning and Afternoon, Oct. 18, 1938

9:30 A.M. A.W.S.; Session on Fundamental Research in Welding; Book-Cadillac Hotel
9:30 A.M. A.S.M.E. and A.W.S.; Joint Technical Session on High Pressure Work; Book-Cadillac Hotel
9:30 A.M. W.A.; Technical Session; Detroit-Leland Hotel
10:00 A.M. Simultaneous Technical Sessions; Hotel Statler
10:00 A.M. A.I.M.E. (Institute of Metals) Session on Bearings; Book-Cadillac Hotel
10:00 A.M. A.I.M.E. (Iron & Steel) Session on Metallography of Iron; Book-Cadillac Hotel
12:00 M. National Metal Exposition opens; Convention Hall
12:00 M. Canadian Luncheon; Hotel Statler
12:15 P.M. A.I.M.E.; Openhearth Executive Committee Luncheon; Book-Cadillac Hotel
2:00 P.M. Technical Session; Convention Hall
2:00 P.M. A.I.M.E. (Institute of Metals) Session on Aluminum; Book-Cadillac Hotel
2:00 P.M. A.I.M.E. (Iron & Steel) Session on Iron Alloys; Book-Cadillac Hotel
2:00 P.M. A.W.S.; Simultaneous Sessions on Fundamental Research and on Oxy-Acetylene Welding and Cutting; Book-Cadillac Hotel
2:00 P.M. W.A.; Simultaneous Technical Sessions; Detroit-Leland Hotel
4:30 P.M. Lecture Course, Machinability; Convention Hall

Tuesday Evening, Oct. 19, 1938

7:00 P.M. A.I.M.E.; Reception and Banquet; Book-Cadillac
7:30 P.M. A.W.S.; Conference and Meeting of Fundamental Research Committee; Book-Cadillac Hotel
8:00 P.M. Lecture Course, Pyrometry; Convention Hall
10:30 P.M. National Metal Exposition closes

Wednesday, Oct. 19, 1938

9:30 A.M. Annual Meeting and Campbell Memorial Lecture; Hotel Statler
9:30 A.M. A.W.S.; Simultaneous Sessions on Welding in Machine Design and on Industrial Research; Book-Cadillac Hotel
9:30 A.M. W.A.; General Meeting and Acid Disposal Symposium; Detroit-Leland Hotel
12:00 M. National Metal Exposition opens; Convention Hall
12:00 M. College Alumni Luncheons; Hotel Statler
12:15 P.M. A.I.M.E. (Iron & Steel) Executive Committee Luncheon; Book-Cadillac Hotel
1:00 P.M. W.A.; Luncheon; Detroit-Leland Hotel
2:00 P.M. Technical Session; Convention Hall
2:00 P.M. A.I.M.E. (Institute of Metals) Session on Corrosion; Book-Cadillac Hotel
4:00 P.M. W.A.; Annual Meeting; Detroit-Leland Hotel
4:30 P.M. Lecture Course, Machinability; Convention Hall
7:00 P.M. W.A.; Dinner and Stag Smoker; Detroit-Leland
8:00 P.M. Lecture Course, Pyrometry; Convention Hall
8:00 P.M. Joint Committee on Physics of Metals; Discussion on Nature of Hardness; Hotel Statler
10:30 P.M. National Metal Exposition closes

Thursday, Oct. 20, 1938

9:30 A.M. A.W.S.; Automotive Session; Book-Cadillac Hotel
9:45 A.M. W.A.; Session on Steel Wire; Detroit-Leland Hotel
10:00 A.M. Simultaneous Technical Sessions; Hotel Statler
12:00 M. National Metal Exposition opens; Convention Hall
2:00 P.M. Symposium on Hardenability; Convention Hall
2:00 P.M. A.W.S.; Automotive Session; Book-Cadillac Hotel
2:00 P.M. W.A.; Session on Rope Wire; Detroit-Leland Hotel
4:30 P.M. Lecture Course, Machinability; Convention Hall
6:00 P.M. National Metal Exposition closes
7:00 P.M. Annual Banquet; Hotel Statler
7:00 P.M. A.W.S.; Dinner; Book-Cadillac Hotel

Friday, Oct. 21, 1938

9:30 A.M. A.W.S.; Simultaneous Sessions on Ships and Railroads; Book-Cadillac Hotel
10:00 A.M. Symposium on Hardenability; Hotel Statler
10:00 A.M. Technical Session; Hotel Statler
11:30 A.M. A.W.S.; Business Meeting; Book-Cadillac Hotel
12:00 M. National Metal Exposition opens
2:00 P.M. Symposium on Hardenability; Convention Hall
4:30 P.M. Lecture Course, Machinability; Convention Hall
10:30 P.M. National Metal Exposition and National Metal Congress end

Technical Meetings

Monday's Program: October 17, 1938

First Morning Session

(Simultaneous)

Typical of ASM technical sessions is the opening paper — an original investigation made at U.S. Steel Corp. Research Laboratories on the *softening rate* of a carbon steel during *quenching*. E. H. Engel is the author.

A different type of paper, somewhat more practical in nature, follows. In it R. L. Rolf tells in more or less non-technical language how *hardening with the oxy-acetylene flame* complies with the modern trend in heat treating toward uniformity, controlled atmospheres, and accurate temperature control. Some interesting automatic equipment is utilized.

Another original investigation on metallurgical fundamentals is detailed by Charles R. Austin and M. C. Fetzer of Penn State College. This concerns the reaction of hyper-eutectoid steels to a *prolonged annealing* at temperatures *above the critical* range.

Second Morning Session

(Simultaneous)

To help dispel some of the confusion arising from the use of five hardness scales, Howard Scott and T. H. Gray have studied the *relationship between* Rockwell C and diamond pyramid *hardness tests*. They find that composition of the steel and its heat treatment have no effect on this relationship (contrary to common supposition).

The difficult job of defining *absolute hardness* and determining it experimentally has been attempted by E. G. Mahin and G. J. Foss, Jr. Their results have been withheld from three previous conventions for further data enabling them now to reach final conclusions.

From Canada comes a paper by ASM trustee O. W. Ellis and J. E. McDonell, who find that *fiber* affects the *notch toughness* of mild steel — longitudinal notch sensitivity is decreased by quenching; transversely it is increased.

Presenting a new method for rapid *determination of carbon content* of molten openhearth steel, B. A. Rogers, Karl Wentzel and J. P. Riott will likewise demonstrate the apparatus.

One Afternoon Session

No program would be complete without several contributions on the ever-important *stainless steels*. The discussion is led off by Russell Franks, who lucidly presents the reasons for *special alloy additions* to improve the chromium and chromium-nickel steels.

"What causes *stress corrosion cracking?*" Hoyt and Scheil frankly admit that the answer is not yet fully understood. Their paper, however, adds much new light on the problem and describes a new test to determine the stress cracking tendencies of the important family of austenitic stainless steels.

Treatment of stainless steel with strong nitric acid has long been practiced for two purposes — cleaning and passivating. Benefits derived from such treatment have been studied by J. N. Ostrofsky of Rustless Iron and Steel Corp., and he finds that weak nitric acid used boiling is better for *passivation of stainless*.

Two Lecture Courses

Afternoon

A course of five educational lectures on *machinability* is opened by Hans Ernst at 4:30. His subject is *physics of cutting*, and in addition to a review of the theory of machinability, he also has some new and unpublished data, the result of experiments on cutting action at low temperatures.

Evening

Robert B. Sosman, internationally known for his studies on silica, lime, and the physical chemistry of other refractory substances, will start a series of three evening lectures by an introductory address on the scientific foundations of *pyrometry*, as it applies to the measurement of temperatures of solid surfaces.

National Metal Exposition Opens at Noon

Technical Meetings

Tuesday's Program: October 18, 1938

First Morning Session

(Simultaneous)

White, Clark and McCollam show that a high degree of *oxidation resistance* at temperatures up to 1750° F. can be secured economically by the proper combination of *chromium, silicon and aluminum* in intermediate alloy steels.

Because some residual aluminum is often incorporated in cast 20-10 Cr-Ni *corrosion resisting steel* to which titanium has been added, a study of the *effect of aluminum* on the properties of the metal was undertaken at Norfolk Navy Yard. Joseph A. Duma reports, among other results, that it improves both the mechanical and corrosion resisting properties.

Molybdenum high speed steels, which have increased so rapidly in popularity during the last decade, have certain inherent disadvantages. Walter R. Breeler reviews the more important modifications in composition developed to overcome these difficulties.

Second Morning Session

(Simultaneous)

An interesting and valuable by-product of an investigation of copper powder compacts being made by C. G. Goetzel is a paper describing certain properties of *oxygen-free high conductivity copper*.

After studying various types of 70-30 *nickel-copper alloys* rendered *subject to precipitation hardening* by the addition of one or more elements, Erich Fetz reaches the conclusion that Monel metal containing a little tin offers definite commercial possibilities.

Seeking to improve the electrical resistivity and oxidation resistance of the 80-20 *nickel-chromium resistor* alloys, A. L. Sanford and O. E. Harder experimented with additions of aluminum, cobalt, titanium and columbium. Aluminum was found to be most beneficial.

One Afternoon Session

The belief that *hydrogen* plays an important part in the development of *flakes in steel* is further confirmed by work carried on at University of Illinois. R. E. Cramer and E. C. Bast also present data on the time of cooling necessary to prevent the formation of internal fractures and the temperature at which they form.

Studies on high temperature oxidation inaugurated at University of Michigan some years ago still continue. Latest studies on the effect of *carbon content* on *oxidation* of steel are reported by C. A. Siebert.

A valuable addition to the subject of grain size control in steel has to do with the *effects of the grain refining deoxidizers* aluminum, vanadium and zirconium in a 1.5% chromium steel. Walter Crafts and J. L. Lamont are the authors.

Two Lecture Courses

Afternoon

For the second lecture in the machinability series, H. B. Knowlton handles the large assignment of *machinability* of ingot iron, wrought iron, S.A.E. steels and stainless steels — and what can be done about it.

Evening

"Pyrometry of metals by means of *thermocouples*" is the scope of Dr. Sosman's second lecture. To limit the discussion to the time available, it considers temperature measurement of solids and surfaces rather than liquids.

National Metal Exposition

Afternoon

Evening

Many meetings of technical societies may fairly be criticized as being too theoretical, dominated by research men and scientists. ASM will never go that way, since the National Metal Exposition, held under ASM sponsorship and control, provides a view of all recent developments in practical metallurgy, metal-working equipment, and metallurgical products.

Technical Meetings

Wednesday

Morning Session

ASMembers' annual opportunity to get together in one place for one big meeting — speeches (brief) from the new officers, and a reward for some deserving chapter.

Then comes the highlight of the technical program — the **Campbell Memorial Lecture.** No Campbell lecturer has failed to live up to the honor, and that General Motors' A. L. Boegehold will have something very much worth while is a foregone conclusion.

Afternoon Session

Schwartz and Barnett add another contribution to their long series of ASM papers detailing investigations into the **graphitizing** reaction. This one attempts to correlate graphitizing rate and nodule number.

Herman F. Kaiser and Howard F. Taylor present not only an excellent review of the recrystallization of iron, accompanied by a complete bibliography, but also some information showing how cold deformation affects **recrystallization** of Armco iron.

Twelve constitution diagrams covering characteristic water quenched and normalized structures of the **iron-carbon-molybdenum** alloys have been established by Blanchard, Parke and Herzig. They provide a useful method of studying fundamental structures after various heat treatments.

Afternoon Lecture

Castings (cast steel, cast iron and malleable iron) are discussed in the lecture on machinability. J. W. Bolton treats the characteristics of the material and their relationship to machining costs.

Evening Lecture

Final lecture in the series on **Pyrometry** by Robert B. Sosman will confine itself to the important aspects of measuring the temperature of surfaces of hot solids by optical and radiation instruments.

Thursday

First Morning Session

(Simultaneous)

Evidence supporting the view that the white layer formed during the erosion of **machine gun** barrels consists of nitrides in solution and not martensite is offered by W. H. Snair and W. P. Wood.

The process of **diffusion in solid metals** is examined by Carnegie Tech's Frederick N. Rhines and Cyril Wells from three angles — structural changes accompanying diffusion, the anisotropy of diffusion, and intergranular diffusion.

Lauderdale and Harder find that contrary to common belief, **carbides** in hypo-eutectoid carbon and low alloy steels go into solution so rapidly at normal heat treating temperatures that they cannot act to inhibit austenite grain growth.

Second Morning Session

(Simultaneous)

Radioactive substances form a relatively new tool in the field of metallurgical research and testing. The possibilities and limitations of such materials for detecting sub-surface defects in metal parts are considered by Herman F. Kaiser.

A six-year program of research on color carbon and **aging** is summarized by Carl L. Shapiro. He adds some interesting new facts concerning aging of aggregates and the effect of particle size on volumetric methods of test.

Numerous investigations have been carried out on **hardness gradients** in steel cylinders, but these have been confined almost exclusively to steel in the as-quenched state. C. A. Rowe and R. A. Ragatz remedy this situation with a study of hardness variations in cylinders that have been tempered after quenching.

Afternoon Session

The first of three meetings to discuss hardenability. For details see the next page.

Afternoon Lecture

For the fourth lecture in the course, A. H. d'Arcambal and W. E. Bancroft consider the machinability of **tool steels.** These are much more difficult to machine than the lower carbon and alloy steels.

Banquet in the Evening

National Metal Exposition

On Wednesday the metal show will be open from 12 noon to 10:30 P.M.

On Thursday will close at 6 P.M. to enable everyone to attend the banquet.

Technical Meetings

Friday's Program; October 21, 1938

First Morning Program

(Simultaneous)

A laboratory method for the preparation of **metallographic specimens** that has been successfully used at the National Bureau of Standards for several years is described by Ellinger and Acken. It is especially suited to soft metals and those containing non-metallic inclusions, ordinarily considered difficult to prepare.

That great interest is centered on metallographic technique is indicated by another method of **polishing** specimens which uses cast iron and lead laps. It is said to promote flatness, freedom from flow of metal, and reduction of inclusions. Tracy C. Jarrett tells about this new technique.

H. K. Work and S. L. Case of Jones and Laughlin Steel Corp. set out to find a simple metallographic test for predicting **sensitivity of steel to cold work,** which could be substituted for work brittleness and aging tests, difficult to make on thin-gage material.

Final Afternoon Lecture

Aluminum, zinc, copper, magnesium and nickel base alloys and bearing metals will be included in the final lecture of the course, on machining **non-ferrous metals,** both cast and wrought. Harry P. Croft will present it.

Symposium on Hardenability

Thursday Afternoon

(Simultaneous)

Let no one be repelled by the title "The Physics of **Hardenability.**" A non-physical abstract of the paper is on page 439 of this issue, and those who attend this session are certain to hear a brilliant and lucid exposition of fundamental principles by the author, R. F. Mehl.

Monumental is the work represented in a paper by Grossmann, Asimow and Urban. The first part concerns effect of variation in hardenability and variation in quenching on **hardness distribution;** the second part gives some quantitative data for **the effects of some common elements** on hardenability.

Studies made by Morris and McQuaid on the hardenability of medium carbon-manganese steels indicate that both **aluminum and silicon additions** are of importance, and that the controlling factor may frequently be non-uniform austenite (as regards carbon content).

Friday Morning

(Simultaneous)

The second session of the hardenability symposium opens with a consideration of the important matter of **hardenability tests** — lucidly handled by General Motors' W. E. Jominy. Fracture tests and hardness surveys (edge to center, or end to end) are now widely used.

Since the outstanding properties conferred by chromium on engineering steels are uniformity and **depth of hardening,** a study of this characteristic of the **low chromium steels** is a logical and valuable addition to the symposium. Walter Crafts and John L. Lamont are the authors.

In the hope of reducing needless duplication of tests by others and of suggesting further lines of investigation, Gordon Williams submits a series of **transverse hardness curves** for several heat treated alloy steels.

Friday Afternoon

The **hardenability line** originated by B. R. Queneau and W. H. Mayo is obtained by plotting fractional depth of hardening for various sized rounds against the inverse square of the diameter — it sounds harder than it actually is, and provides a simple, rapid and reproducible index of hardenability for engineering alloy steels.

In preparing a paper on the hardenability of **plain carbon steels,** John L. Burns and G. C. Riegel made some investigations which show a definite relationship between hardenability, (as expressed by the area under the hardenability curve) the analysis of the steel and its grain size.

G. V. Luerssen points out that hardenability in **small sections** is a particularly fruitful field for study, since slight variations in the factors influencing hardenability cause large variations in the properties of the finished part.

Last chance to attend

The National Metal Exposition

Noon to 10:30 P. M.

Personals

William A. Reich, Carnegie Institute of Technology 1938, is now working for General Electric Co., taking a training course.

Transferred: **A. M. Belfry**, from Chicago office to Minneapolis office, Minneapolis-Honeywell Regulator Co., in the Industrial Division.

Promoted: **George P. Kraemer**, from manager of the Philadelphia branch to vice-president of Edgar T. Ward's Sons Co., Pittsburgh.

Fred Grotts has resigned as vice-president, Lebanon Steel Foundry, to become vice-president, Chicago Steel Foundry Co., taking charge of production and sales of heat and corrosion resisting alloys.

Carl W. Horack has left the faculty of University of California and is now with the Merco-Nordstrom Valve Co., Oakland, Calif., as assistant engineer.

H. F. Scobie has left American Hoist and Derrick Co., St. Paul, to become a foundry instructor at the University of Minnesota.

R. J. McGuigan has resigned as chief metallurgist, Wheeling Steel Corp., Steubenville plant, to become chief metallurgist, McKeesport Tin Plate Corp., McKeesport, Pa.

Donald R. Bowman is now employed in the metallurgy laboratory of Delco Appliance Division of General Motors Corp., Rochester, N. Y.

Transferred: **Forrest J. Couch**, from factory engineering department, Rochester, N. Y., to headquarters of engineering, American Foundry Machine Co., Cincinnati, Ohio.

Otto Zmeskal has been made assistant in the department of metallurgy, Massachusetts Institute of Technology, working toward his Sc.D. in physical metallurgy.

Walther H. Mathesius has left the staff of U. S. Steel Corp. Research Laboratory, Kearney, N. J., to join the metallurgical department of National Tube Co., National Works, McKeesport, Pa.

Ralph Schaper has left Smith Steel Foundry Co., Milwaukee, as chief inspector, to join Lebanon Steel Foundry, in charge of sand control work.

Adolph Bregman, metallurgical engineer, formerly managing editor of **Metal Industry,** has established an office in New York as a consultant in the metal products manufacturing and metal finishing industries.

George E. Burks has been made assistant chief engineer for Caterpillar Tractor Co.

How

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METAL PROGRESS

An A. B. C. Publication

A.B.C. = Audit Bureau of Circulations = FACTS as a yardstick of advertising value

Personals

Harry M. St. John has resigned as chief metallurgist, Detroit Lubricator Co., to become superintendent, non-ferrous division, Crane Co., Chicago.

Marvin J. Bair, formerly in the sales department, Greer Steel Co., is now selling for Thomas Steel Co., Warren, Ohio.

Granted leave of absence: R. W. Sandelin from Atlantic Steel Co., Atlanta, Ga., to continue work on doctorate in metallurgy and metallography at University of Minnesota.

W. F. Carter, formerly metallurgist at Union Special Machine Co., and instructor of metallurgical fundamentals at Lewis Institute, has joined the metallurgical staff, Acme Steel Co.

Appointed instructor, Department of Mechanical Engineering, Michigan State College, East Lansing, Mich.: C. W. Hangosky, formerly with Carborundum Co. and Simonds Saw & Steel Co.

John L. V. Bonney, Jr. is now with Carnegie-Illinois Steel Corp. as an observer at the Duquesne Works.

Louis Ziffrin, formerly with the metallurgical department of Carnegie-Illinois Steel Corp. at Chicago, has been placed in charge of metallurgical research and development for the Edison General Electric Appliance Corp.

Robert V. Jones is now employed as metallurgist at National Malleable & Steel Castings Co., Sharon, Pa.

Made sales engineer for R. C. Neal Co., Inc., Syracuse: Orson B. Randell, formerly with Tagliabue Mfg. Co.

William C. Schulte has left Lukens Steel Co. to become assistant professor of mechanical engineering at Rutgers University.

V. W. Vaurio has accepted a position as special representative with the department of inspection, Tennessee Coal and Iron.

Ray C. Kasper is now employed as metallurgist in the Pan American Petroleum and Transport at Texas City, Texas.

ASMember Gilbert C. Hoover, U.S.N. will be in charge of the armor and projectile section of the Bureau of Ordnance until October, and will then take charge of the experimental section for the next three years.

Transferred from Farmall Works, International Harvester Co., Rock Island, Ill.: G. F. Jontz, to the truck engine division at Indianapolis.

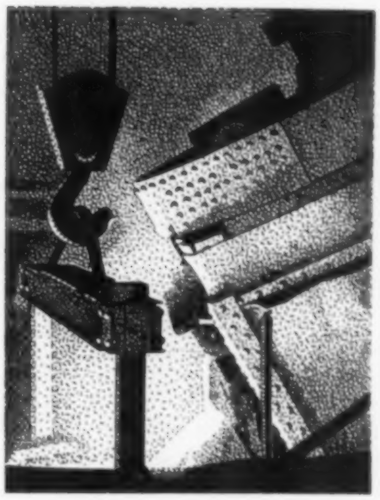
S. L. Weaver has been transferred from the Cleveland to the Chicago office of American Steel and Wire Co., as contact man in the operating department.

STEELS AND IRONS

METAL PROGRESS OCTOBER, 1938

Carbon & Alloy Steels,

Tool Steels, Castings



Melting Quality Steel

By William J. Reagan
Asst. Supt. of Openhearth
Edgewater Steel Co., Pittsburgh

IN THE manufacture of medium and high carbon, fully killed steels, usually known as "forging quality" steels, extreme care is needed at all points in the operation in order to produce really high quality. Much discussion has ensued in trying to define quality, and it can be stated that it is a relative factor. In practice the cheapest steel that will have the desired properties is the controlling factor.

Before starting to control quality in the furnace we should have available a sharp working furnace with which the desired heats may be made without retaining the metal in the furnace for an undue length of time. Naturally a furnace with atmosphere control and temperature control of the reversing cycle helps materially to maintain uniform furnace practice. Uniformity, after all, is a large factor in producing quality steel.

This uniformity starts with the selection of the charge and of the percentage of lime to be charged. It should be such that for a given grade of steel it is possible to make a large number of heats with similar types of material. The lime depends upon the metalloids in the charge (mainly the silicon) and also upon the lime-silica ratio desired in the finishing slag. Usually a lower percentage of lime than actually needed is charged and, after melting down, additional amounts may be added until the desired lime-silica ratio is obtained. The lime charge is quite an important part of furnace practice as in addition to controlling the physical and chemical properties of the slag it has considerable effect upon the speed of the furnace; usually the lower the lime charge the faster the operation. Lime may be either burnt lime or raw limestone, burnt lime being preferred because it increases operating speeds.

Heats should be melted down so that the carbon is sufficiently high to allow for a good feed of ore and to insure sufficient time for shaping the slag before the final deoxidizer is added. It is also poor judgment to spend too much time in shaping up the slag. Uniform control of furnace atmosphere is helpful in having heats melt at a uniform carbon; it also eliminates to a large extent the personal factor.

After the heat is melted down shaping the slag is one of the most important and interesting phases of steel production. Use of the viscosimeter to control slag viscosity, and use of the pancake method of appraising the chemical composition of the slag have helped materially; future developments promise rich rewards for experimentation in this field. In addition to controlling the chemical analysis of the finished steel, slag control also helps control the working of the heat by affecting the elimination of carbon. Gradually our knowledge of this most important reaction is being increased. Use of the carbometer is quite extensive and gives the melter accurate carbon determinations in a very few minutes. This in turn gives him a more accurate picture of the progress of his heat and affects materially the time of the heat. Slag control is largely effected by the use of burnt lime, iron ore (fine) or mill scale and fluorspar and, of course, temperature. Other materials have been used, of which we will learn more by experience.

The type of deoxidizer depends largely upon plant practice and specifications to be

met, with ferrosilicon, spiegel and silico-manganese being quite generally used. One cannot as yet say which is the best type as many factors affect the selection. However it has been found that heats deoxidized with silico-manganese, and tapped dead killed a definite time after the addition of deoxidizer, produce a very uniform quality steel.

Once the heat is tapped from the furnace it is even more important to maintain good pit practice. The main points are discussed by another contributor; they pay large dividends by reducing the percentage of rejections. It is the writer's opinion that each grade of steel has a best type of mold (which means shape and wall thickness) and also a best casting speed and temperature. Only experience will indicate which is best; *commercial* steel production often prevents using the one best type.

There seems to be no question that the future will show an increase in the use of furnace insulation, material changes in furnace design and a large increase in the use of instruments to control various features of furnace operation. The more the human element can be eliminated the more uniform our steel making practice will be.

When we think of the tremendous reaction speeds obtained in the Portevin process we can readily picture the possible application of this or similar schemes for increasing the speed of reactions in the openhearth process.

Manufacture of basic steel has improved materially during the past ten years, as indicated by the large tonnage of alloy steels made today by this process. The future certainly has hope of increased knowledge, and promises much interesting research to improve our present knowledge of quality steel making.

Refining Methods

By John Chipman
Professor of Metallurgy, Massachusetts Institute of Technology
Cambridge, Mass.

IN RECENT YEARS openhearth operators have given considerable attention to their raw materials. Especially attention has been focused upon the quality of pig iron and its effects upon the properties of the finished steel. Research workers have been seeking a mysterious factor in pig iron which apparently influences its behavior in the openhearth, a factor which does not appear in the ordinary chemical analysis of pig iron. While it may have something to do with the temperature at which the cast is made, the factor itself appears to be something more subtle than mere temperature.

Prior to the development of methods for the determination of non-metallic inclusions it was customary to ascribe most of the ailments of pig iron to non-metallic inclusions or "dirt". A recent very thorough investigation of the non-metallics in pig iron and in the steel made from it has shown that there is absolutely no correlation between them. It is hoped that this will be accepted as proof of the innocence of inclusions.

Specifications and analysis of pig iron for use in the openhearth vary quite a good deal from one locality to another. Steel is successfully made from all of them, yet if a given openhearth attempted to use hot metal which varied over this entire range, the difficulties would be enormous. The steel maker must know in advance the approximate composition of the iron going into a given heat; once a practice is set up its success and uniformity will depend largely upon the uniformity of the pig iron. This implies uniformity not only in chemical composition but in the temperature at which the iron is cast and at which it is received.

It seems not at all unlikely that the mysterious factor which we have been seeking is really no more nor less than uniformity from cast to cast. If this be true, it should be readily possible to obtain a quantitative measure of our mysterious factor by the methods which are already familiar to statisticians. Perhaps in the future when openhearth operators get together to discuss mutual problems, they will be asking each other what their blast furnaces are capable of doing in the matter of furnishing iron of low standard deviation!

The importance of statistical methods in the control of manufacturing processes has long been recognized and simple methods for the systematic treatment of the variables of manufacturing have been developed. Their application to steel has, in many cases, permitted a very direct and positive determination of the sources of defects resulting in excessive rejections. If this is capable of doing nothing more than settling the numerous arguments which are always current in superintendents' meetings it would amply justify establishment of a statistical division attached to the metallurgical department of every large steel mill.

Refining of hot metal with soda ash to decrease its sulphur content has been used by grey iron foundries for many years. The application of this principle to the treatment of hot metal for steel manufacture has constituted the

most radical recent advance in steel making, especially in the use of low grade ores of European countries. The operation of the blast furnace on an acid slag produces low cost iron of high sulphur content which would be quite unusable in the openhearth without the desulphurizing treatment. Use of soda ash in desulphurizing has thus opened up vast reserves of low grade iron ore.

In recent years we have heard much regarding slag control in the openhearth. The meaning of this term in different plants ranges from a scientific control of the whole openhearth cycle to the pouring of a little slag on the floor to see what it looks like. The object of slag control is, of course, to maintain the greatest possible uniformity from heat to heat, and to control the many variables of furnace practice within the most favorable range. In general this is now being done by controlling the ratio of lime to silica and controlling percentage of iron oxides in the slag. No single device can accomplish this control, which depends rather upon the establishment of a systematic procedure which may vary considerably from one plant to another.

Slag control begins with the control of the charge and the more accurately the charge can be specified, the easier the slag control problem becomes. When a charge varies over a wide range it is generally necessary to make adjustments in the composition of the slag during the making of the heat. Some very useful guides to this adjustment have been worked out. The simplest of these is the visual examination of a slag pancake by means of which the skilled observer is able to estimate the lime-silica ratio, and sometimes to tell you also its content of iron oxides, manganese oxide and the phosphorous content of the bath. Determination of the viscosity of the slag at certain times during he heat has formed the basis for one of the most successful systems of slag control.

Deoxidizing Agents

By R. C. Good
Metallurgical Engineer
Electro Metallurgical Company, New York

MORE than average attention has been given to the deoxidation of steel in the last 20 years, and today every metallurgist realizes that the physical properties in the solid steel reflect the kind of deoxidation. New principles and methods have been established from time to time and correlations between microscopic examinations and chemical analyses of the oxides have been worked out gradually, so that it is obviously difficult to assign any particular development to one year.

Deoxidation of steel is purposely varied from minimum additions sufficient to control rimming in molds to a maximum removal of oxygen desired for dense, clean steels acceptable only when the oxygen content is as low as possible. In every case, the best results are procured by basing the deoxidizing practice on conditions most likely to prevail prior to the addition of the reagents.

Numerous combinations of elements into one alloy have been proved effective after exhaustive trials and experiments. Several such alloys that are meeting demands today will now be briefly noted.

Silico-manganese in proper proportions, when added in the furnace, will form inclusions of low melting point approaching the formula $2\ MnO \cdot SiO_2$ which float to the surface rapidly; success may be estimated by calculating the amounts of manganese and silicon oxidized. Additions of high carbon pig iron ahead of the silico-manganese improve the practice. *Ferro-manganese* (medium or low carbon) is preferred by operators who wish to avoid CO gas that is generated after an addition of the high carbon spiegel, since carbon exerts a powerful attraction for oxygen at high temperatures. Dissolved CO gas in liquid steel containing silicon would be eliminated when it solidifies.

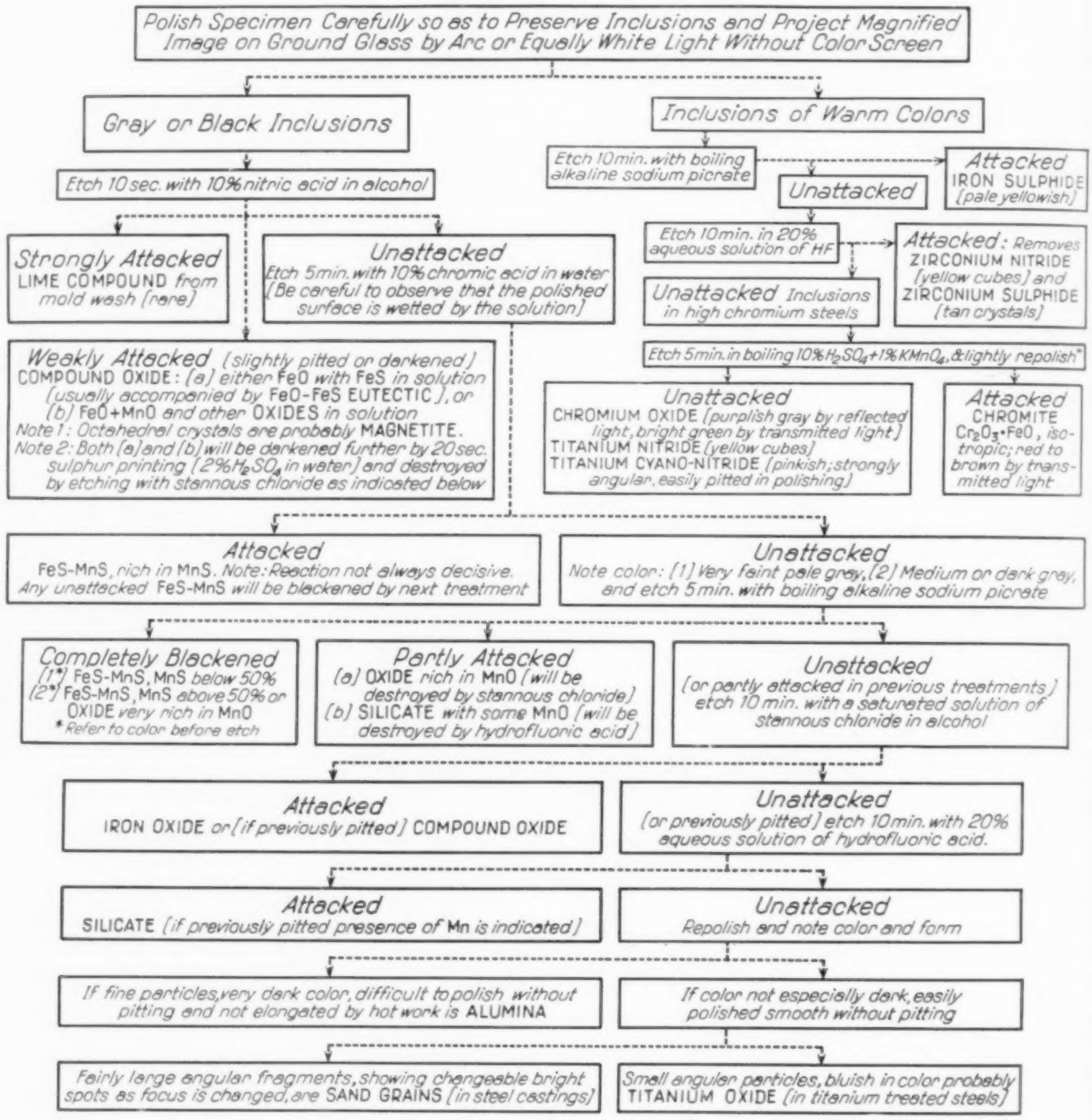
Zirconium-silicon alloys are frequently added in electric furnaces to coagulate and aid the removal of other oxides by lowering their melting points. Zirconium also unites with sulphur and nitrogen, rendering the steel more machinable and malleable. It is commonly used in conjunction with the higher manganese grades, whereupon the steels show less segregation on account of the added deoxidizing effect.

Calcium alloys, such as calcium-silicon or calcium-manganese-silicon, are far more effective in removing oxygen than is silicon alone, and the products of deoxidation do not remain in the steel. Since the calcium is strongly basic with respect to silicon, fluidity of both slag inclusions and steel is noticeably improved. From two to six pounds per ton are effective when the alloy is added in the ladle.

A grain refining combination of silicon, vanadium, aluminum and zirconium known as "Silvaz" is also a suitable addition to the ladle. It improves impact resistance and elastic ratio by its influence on the non-metallics. Since combinations of grain refining elements are

Method for Identification of Inclusions in Iron and Steel

Originated by Wm. Campbell and G. F. Comstock (Proc. A.S.T.M., Vol. 23, p. 521) and Modified by C. R. Wohrman, Merrill Scheil and Miss M. Baeyertz



* Note: Suitable only for stainless steels with clean (unoxidized) surfaces.

Supplementary Tests

In all instances check determinations in the light of the evidence of a careful chemical analysis, and, whenever possible, by other methods, such as:

I Sulphur Printing

(for 20 sec. using a 2% aqueous solution of H_2SO_4)

(1) Dissolves all FeS-MnS inclusions

(2) Partly dissolves (pits) FeO containing FeS and OXIDES of other metals in solution

(3) Leaves unchanged: IRON SULPHIDE (pale yellow), pure IRON OXIDE (medium grey), SILICATES (dark grey)

II Matweieff's Tests

(a) Dilute tartaric acid does not attack OXIDES or SILICATES, but colors MnS lightly and FeS decidedly

(b) Heat sample in hydrogen at 1600°F., OXIDES are reduced, SILICATES and SULPHIDES are unaffected

(c) Repolish (b), etch with dilute $FeCl_3$ in alcohol; if reduced oxide particles are colored deeply they contain some Mn

III Rohl's Test for Sulphides

Short etch with 1% picric acid in alcohol, then temper to dark yellow. FeS turns dark blue to reddish violet, and MnS turns dull gray to bright white.

often found to be more stable and effective than individual elements, the proper amount of Silvaz provides a clean, fine grained steel with superior properties.

While the above general practices are in common use, the preliminary oxygen content of the steel must be under control — most easily by manipulating the amounts and proportions of the materials and the charging order.

Pit Practice

By Leo F. Reinartz
Manager, Middletown (Ohio) Division
The American Rolling Mill Co.

IN A MODERN openhearth shop the type of equipment and the efficiency of the operations on the pit side of the furnaces have a vital and often controlling influence on the quality and cost of steel ingots produced by that plant. Not that these operations are so very complicated, but it does mean that eternal vigilance and attention to every minute detail is the price paid for quality production. Teeming of a heat of steel is quite an art. The personnel in a pit must be alert, courageous, well-balanced, conscientious and imbued with the quality idea.

Equipment must be ample and sturdy enough to handle the work in this area with dispatch, including high capacity cranes designed to require minimum maintenance and having relatively high speed to convey the molten steel in ladles from the pit to the teeming platform.

Ladles may vary from 100 to 175 tons in capacity. Oval all-welded ladles are becoming very popular. These ladles can be cleaned easily and allow the operator to tap at least 4% more steel out of a given furnace due to their lighter weight.

A dense, fairly low melting point brick has given best results for ladle linings. When heated by the hot metal they swell and close all cracks. The life of the lining depends on the type of steel, amount of slag carried on top of the metal, and the time it takes to teem a heat. Where high carbon killed steels are teemed it is common practice to slurry the ladle after each heat — very often with a cement gun.

Nozzle and sleeve bricks should be hard burned in the kilns. Managements should insist on strict adherence to design and dimensions. These bricks should be thoroughly dried and seasoned by placing them between checker chambers for several months, and then heated before placing in the ladle. One man should be assigned to the job of making up stopper rods. Every detail of this assembly should be standardized and strict adherence to standard practice demanded. This refers to size of rod, threads, keyway slots and keys, as well as stopper rod bolts and heads.

Setting a nozzle requires very careful work. The size of the nozzle for each type of steel must be selected with care since a different rate of pouring is required for almost every kind of steel, whether alloy, killed, or rimming steels. Nozzle cups should be ground true if not in this condition when nozzles arrive in the plant. The lower part of a nozzle should be painted with graphite to avoid "bugs" or steel drippage freezing in the nozzle which will cause the metal stream to spray. Loam used for ramming in nozzles must be free of grit or pebbles; it is good practice to add 10 to 15% first quality fireclay to make it more plastic. Care must be taken to have the nozzle vertical when rammed in place. The cup must be cut just right; if cut too deeply, steel may freeze in it and cause trouble in pouring; if cut too shallow, the stopper rod may jump out of position and the pourer lose control of the teeming.

Molds must be thoroughly cleaned before sending to the pit. Either graphite or tar is ordinarily used as a mold wash, but whatever coating is used it must be applied uniformly to give good results. Molds should not be much over hand warm for best results in teeming.

Some plants, particularly those making ingots for plates, bottom pour their steel. This practice, to be successful, must be watched very carefully. Better surface on killed steels at the least expense to internal structure is the goal striven for. Rimming steel is usually top poured. These ingots, if properly made, have good surface but may suffer from unusual segregation in the upper part. Hot tops in most instances are used with big-end-up molds in killed, high carbon and alloy steel practice to increase the yield of sound steel from an ingot. They hold 12 to 15% of the metal.

If aluminum is added to the molds, as is

often done in rimming practice, the additions must be made regularly and uniformly. Great judgment must be exercised in this operation.

The best equipment is useless and even dangerous unless proper inspection and maintenance practices are followed. It is simply ruinous to have heats in ladles ready to teem and then have something go wrong with, say, the control mechanism of the ladle crane.

Pit practice in recent years in most shops has improved very materially because plant managers realize that poor pit practice neutralizes the best work of efficient melters.

Improved Sheets and Sheet Mills

By John B. Tytus
Vice President in Charge of Operations
The American Rolling Mill Co., Middletown, Ohio

TODAY, all the principal manufacturers of steel sheet are equipped with continuous mills. Although this is a comparatively recent development, so rapid has been the progress that within the past 15 years, production facilities have been completely revolutionized, organizations have been skilled in the new technique, and the major difficulties incident to such a sweeping change have been solved. For the majority of purposes, the sheets now produced by these new methods are far superior to those produced by the older methods.

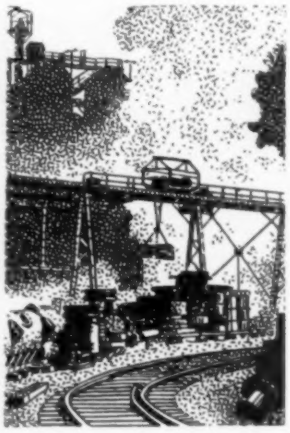
The sheet and strip branch of the iron and steel industry is now consolidating its gains by working on the finer points of gage, surface, and metallurgical qualities. We all recognize that a higher degree of perfection is attainable because of greater technical knowledge and better control. Development of the continuous process itself required the exploration into unknown realms in the quest for more accurate technical data on rolling than existed before, as well as the discarding of many opinions and theories of long standing. Certainly the continuous methods can control the product far better than was ever possible under the more-or-less manual methods of former days.

The hot-and-cold strip method of production has proved so much less costly than older methods of producing sheets from sheet bars that one of the present problems is to equal or improve on the quality of the hot rolled sheet still produced by hand rolling for certain purposes and small orders. It is, of course, a well-known fact that for industries such as the automotive, household refrigeration, and others employing mass production methods the hot-and-cold sheet has proved its superiority and its economy. However, there are still some smaller miscellaneous users whose requirements for various reasons still remain to be met satisfactorily. In this present period of low operations the sales, research and production departments, by working in close cooperation, can solve the problems involved and perform a service of mutual profit.

It is generally admitted that the continuous process has been responsible for the gradually falling trend of sheet prices. We are now living in an era of low unit costs and large volume production. The consumers of our products — our customers — are driven by necessity to lower and lower costs, just as we are, in order to secure the volume of sales necessary for profitable operation. They are taking advantage of every possible opportunity, and this undoubtedly accounts for the tendency to purchase coils wherever their use may result in lower handling costs and less scrap.

This same economic incentive is the reason why, in my opinion, the major effort of the next few years will be devoted to engineering refinements which reduce waste, increase efficiency, and improve quality.

The strip process of making sheets has greatly reduced scrap loss, as every manufacturer knows. The older methods of manufacturing sheets in packs required liberal width and length allowances which had to be sheared off in order to secure a pattern sheet. With the strip method there is practically no loss in length and the scrap loss in width has been materially reduced.



However, the raw material for manufacturing the modern strip is the slab, rolled from an ingot with a loss running around 15%. For more than 50 years the ingenious and imaginative men of the industry have been striving and planning to develop a commercially practical method whereby this source of waste can be eliminated. With all the thought being given this problem, I have the feeling that some day a better way will be developed.

Strong Structural Steels

By C. H. Lorig
Battelle Memorial Institute, Columbus, Ohio

THE TECHNICAL and industrial developments leading up to the present status of the low alloy, high yield strength steels came simultaneously. To the designing engineer, conditions were ripe for reductions in dead weight without sacrificing strength; concomitantly metallurgists, through increased knowledge of the effects of specific alloying elements, were developing steels of low first cost, of high yield and tensile strengths, and of improved corrosion resistance. These properties fitted them for commercial use in the new designs.

Strong structural steels are not new; they have been available for the past 30 years. The first of these steels depended on 3.0 to 3.5% nickel and medium carbon for strength, high yield, ductility, and toughness. Then came the steels with carbon, manganese, and silicon used in various moderately increased proportions to which copper was sometimes added to increase the atmospheric corrosion resistance. Chromium was later introduced in steel of the latter type, primarily to avoid variations in yield strength between the light and heavy gages.

More recently, however, requirements have multiplied so that some of the earlier steels no longer are entirely satisfactory. High yield is sought, but besides high yield strength, the low alloy structural steels now require low first cost, excellent welding and fabricating properties, toughness, high endurance limit, moderate resistance to corrosion in the atmosphere, and insensitivity to finishing temperatures and to variations in mill practices. They must be suitable for use "as rolled" and generally be low in carbon. It is not easy to obtain all this in the same steel.

Metallurgical progress of recent years has helped the situation by providing new alloy combinations and more precise information on the influence of the individual elements. Copper, for instance, was long known to be a strength-giving element; yet until it was found possible to combat surface checking of copper steels on hot working by the introduction of a small amount of nickel, copper was used sparingly. Now it is found in combination with nickel and other elements in a number of steels in amounts to produce desired strength and high yield ratio. Phosphorus is another cheap element which is rapidly finding a place for two very good reasons; first, phosphorus is a potent alloying element, providing high yield strength and yield ratio, and, second, it increases the resistance of the steel to atmospheric corrosion. Phosphorus contents in the range from 0.07 to 0.20% are common.

The results of this progress have led to the development of many low alloy, high yield strength steels, practically all of which rely upon combinations of elements with proper or balanced proportions rather than upon a single element or carbon for their properties. The total alloy content is usually less than 4% and often below 2%. These combinations include the following:

Nickel-copper	Chromium-silicon-copper-phosphorus
Copper-molybdenum	Manganese-copper-molybdenum
Copper-phosphorus	Manganese-copper-phosphorus
Copper-chromium	Chromium-nickel-phosphorus
Chromium-molybdenum	Chromium-manganese-silicon
Manganese-copper	Copper-chromium-manganese
Manganese-nickel	Manganese-copper-vanadium
Nickel-copper-phosphorus	Manganese-silicon-copper
Nickel-copper-molybdenum	Chromium-nickel-copper

There are too many steels being offered for all of them to survive. Even the present situation exists only by virtue of the fact that each steel producer has one or two or three favorite combinations — no one tries to make all of them on order. Some will not survive present competition; others will be improved; still others will be begot. However, those that survive will be low in first cost and most qualified to meet the various requirements for good performance in the mill and service. The commercial development in their preparation and use has brought us into an epoch of industrial life in which speed, light weight structures, and rapid expansion in new uses for steel are paramount factors. Realization of economies from weight reduction, and new applications, will stimulate consumption of these steels.

Cold Finished Steels

By Y. J. Bruce
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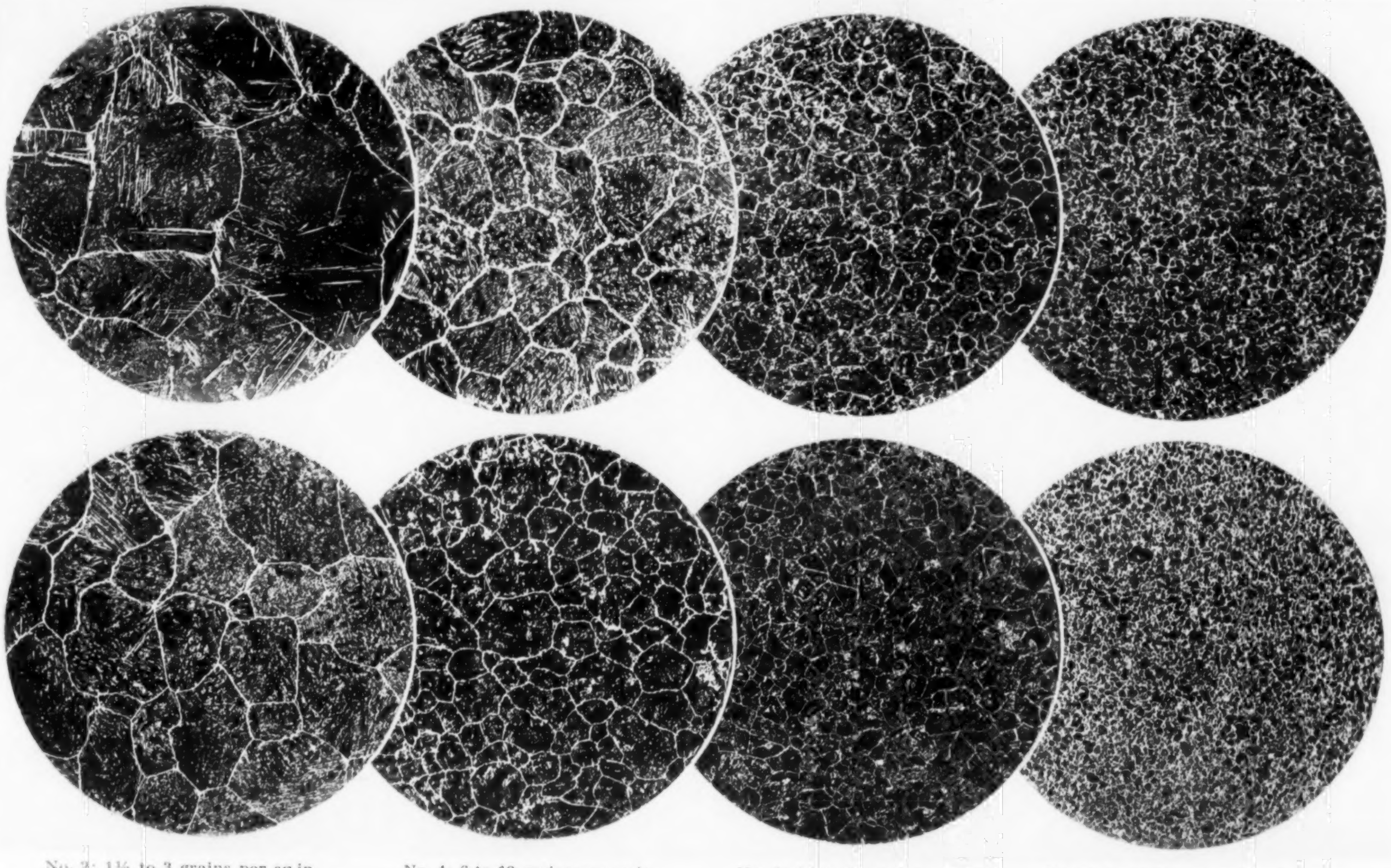
Pittsburgh, Pa.

COLD FINISHING, as understood in the steel industry, covers more than the process of reducing the cross sectional area of a bar without any heating, including as it does grinding, turning, polishing, cold rolling, and various combinations of all these processes. Use of such materials has grown rapidly; 1938 has been no exception. This has in no small part been due to a better understanding of the relationship between steel making processes and the precise

Standard Grain Sizes for Steels

Carburized and slowly cooled to develop cementite network. Magnified 100 diameters. Micros courtesy Timken Roller Bearing Co.

Grain Size No. 1; Up to 1½ per sq.in. No. 3; 3 to 6 grains per sq.in. No. 5; 12 to 24 grains per sq.in. No. 7; 48 to 96 grains per sq.in.



No. 2; 1½ to 3 grains per sq.in. No. 4; 6 to 12 grains per sq.in. No. 6; 24 to 48 grains per sq.in. No. 8; More than 96 grains per sq.in.

properties desired for cold finished bar stock. Especially noteworthy has been the improved mechanical control and operation of bessemer converters, where much of the steel for feeding automatic screw machines originates.

Surface of the bar as it reaches the cold finishing department is of importance. This means extra care in soaking pits, and blooming mills, with a progressive revision of standards of billet preparation and conditioning. Some bar mills use hydraulic sprays for descaling and others will be changed over to this system very shortly. Hot beds and equipment for controlled cooling of the bars are also receiving study.

In the actual cold finishing, many seemingly minor improvements go unnoticed to the casual observer, yet have been definite steps forward in one or more plants. To this group belong changes in pickling and cleaning practices, draw benches, rubber, brass or composition rolls and belts to prevent handling marks, improved cut-off and straightening equipment. Of more general application has been the rapid trend from solid steel dies of all types to carbide insert dies, resulting in better size uniformity, closer tolerances and good finish.

In the field of finish it seems fair to mention that some phases of the subject are overworked, especially when one remembers that there are many applications of cold drawn steel where the entire surface is removed in automatics. However, a generally improved surface is one of the phases of the industry where developments of a general nature are spread over the field at large.

Heat-treatment after rolling or drawing, combined with the physical changes brought about by cold drawing itself, has resulted in far better physical properties. While this has been practiced over a comparatively long period of time, the past year witnessed considerable concentrated effort and engineering work for specific applications. The emphasis related principally to strain drawing or tempering, normalizing, and controlled cooling.

The commercial introduction during the current year of steels containing lead for better free cutting properties has attracted much attention. The amount of lead used is approximately 0.25%, and it is now generally conceded that this amount appreciably improves the machinability. This will be a forerunner of other products of a novel character, and of a different trend than those of the past, in which an increase of sulphur has bettered the machinability of the old standardized steels.

Grain Size

By Martin Seyt
Tetragonal Lattice Mfg. Industries, Inc.

POSSIBLY the greatest advance made during the past year in respect to grain size has been the more widespread understanding of grain growth in steel and its application to industrial problems. Whereas a few years ago all grain size tests consisted in making a McQuaid-Ehn test, possibly reporting the results as "inherent" grain size, today commercial practice tends to weigh it against other possible tests, with understanding of their significance.

This does not by any means imply any sudden lessening in the use of the McQuaid-Ehn test or anything improper about its use. It does imply however that, in the cases where it is used, there is much more understanding of its significance. Thus its significance when applied to carburizing steels is well realized, namely that the microstructure after a McQuaid-Ehn test shows whether or not the coarsening temperature of the steel (particularly of the carburized case) has been exceeded.

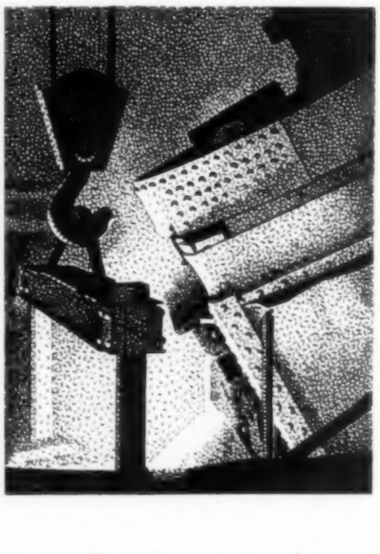
The same comment applies to the non-carburizing steels — those which are hardened at temperatures below 1700° F., most of them possibly in the neighborhood of 1500° F. For these steels the heating time is of course much less than 8 hr., being most often in the range 5 min. to 1 hr. If the grain coarsening test for these steels is a McQuaid-Ehn test, it is realized that the behavior after 8 hr. at 1700° may not reflect the behavior at 1500°, particularly if the steel has coarsened in the 1700° test. The *time* is also to be taken into account.

In steel manufacturing plants there has been further understanding of the significance of the coarsening temperature, and how it is affected both by aluminum additions to the molten steel and by treatment of the final product in rolling. The exact kind and amount of the addition and the proper time (either to the furnace just before tap or to the ladle) have been worked out carefully in the openhearth plants, and in the majority the information is guarded as a close secret. McQuaid-Ehn specifications can therefore be more or less readily met by all important steel makers.

There remains, however, considerable work to be done in explaining to the general user of steel the nature and significance of the term "grain size". Thus the writer of a recently pub-

lished paper, who was a mechanical engineer, complained that the terminology in metallurgical papers is in a very confused state. He cited with justice the fact that papers are still being published which refer to "inherent grain size", "austenite grain size" and "McQuaid-Ehn grain size", without defining clearly what was meant. This will probably be remedied with better understanding of grain size phenomena.

A guess may also be hazarded that grain size specifications in the future may become of less interest. This is due to the fact that one of the reasons for specifying grain size has to do with its effect on hardenability. Since there is a trend today toward defining hardenability more closely in quantitative terms, it may be that the grain size effect, which has up to now been specified separately, may merely constitute one aspect of hardenability. Good hardenability is also relied upon to insure good machinability, when steels hardened and tempered for use (say to 350 to 400 Brinell) are to be machined — as is the trend in certain mass production items.



Engineering Steels

By Ernest E. Thum
Editor, Metal Progress

A YEAR AGO a review of the trend in American steels of S.A.E. classification, and similar ones not on the official list, stressed the point that the extras charged by the steel mills were a most important factor controlling the popularity and use. In other words, if equivalent physical properties can be secured from two, or three, or four well-made steels, the choice would naturally gravitate to the one that could be laid down in the customers' mills at the lowest cost per pound.

This trend still continues. The result is that the higher alloy nickel steels, nickel-chromium steels and nickel-chromium-molybdenum steels in the S.A.E. classification are badly handicapped as to price. Sometimes they are indispensable, but the ideal of metallurgists is always to secure the cheapest oil hardening steel that will give the required properties of parts in mass production. The steel should be oil hardening to avoid the warpage associated with water quenched articles. Necessary strength is had most economically by increases in carbon and manganese, and toughness and ductility secured by controlling the hardenability by means of proper openhearth refining and judicious use of aluminum.

In many cases the trend has gone so far as to replace alloy with straight carbon steels. (As a matter of fact, the manganese is up in these steels, but not high enough to take much if any price extra.) All applications stand or fall on the successful control of hardenability — a matter that is now getting the most attention from producers and consumers of engineering steels.

Carbon-molybdenum steels have now been used long enough to have firmly fixed themselves as a very useful member of the family of alloy steels capable of severe services. S.A.E. 5100 chromium steels carry a very small extra over base price. More or less modified with manganese, and made and used under conditions which strictly control the hardenability, they are spreading in use, since they approach the quality of the old and most popular but relatively expensive chrome-vanadium steels. Carbon-manganese steels — long a favorite in some automotive services — are being modified by adding silicon and molybdenum.

Much still remains to be discovered about the essence of grain size control. In this instance, as in many others, practice precedes theory. We, probably, in this country are approximating on a grand scale some of the essentials the Swedish iron masters have been practicing for generations. Lacking pure raw materials we pay more attention to taking things out of the charge and strict control of the metalloids (and incidentally of unanalyzed gases). Both produce a tough, shallow hardening carbon steel of really excellent quality.

American practice has changed in this direction because of urgent demands for economies from the large customers; possibly British conservatism in the matter of hardenability control is a reflection of an existing dominance of steel producers over steel consumers.

Machinability

By S. L. Widrig

Metallurgist, Spicer Mfg. Corp., Toledo, Ohio

MACHINABILITY is a thing that means different things at different times and in different shops. Probably at any date records in a steel mill's files would show that a heat of steel split between two firms making substantially the same item would be quite "machinable" in one shop and "hard to machine" (even rejected) in the other.

Likewise the question depends on equipment. Whereas 15 years ago a machinist would have trouble with steel harder than 200 Brinell, millions of heat treated alloy steel forgings 400 hard, are now successfully turned, drilled, milled and broached. In the intervening years machine tools have been increased in mass, size, power and freedom from chatter, and cutters have been made stronger, harder and tougher.

Aside from these extremes, the metallurgist who works with steels in the medium ranges is coming to believe that there is a very close relationship between machinability and brittleness (impact value) of steel. Those steels which exhibit low impact machine much more readily than those tough ones with high impact values. Machinability is also correlated with hardness — at a given hardness, the lower the impact the better the machinability. As the hardness is raised, however, a point is reached where the increased hardness offsets the normal drop in impact and machinability becomes more difficult. Cold working also aids machinability, a fact also correlated with impact values.

The microstructure of the various constituents also plays an important part. When the carbide is spheroidized the steel is more difficult to machine than though the ferrite were discontinuous, as in the lamellar pearlitic form.

Usually coarse-grained steels are more readily machinable than fine-grained steels. This also is correlated with the lower impact associated with coarse-grained steels. The inherent or austenitic grain also has its effect. Those steels which are inherently coarse grained machine more readily than those which are fine grained. Tests have shown that when two medium carbon steels, one inherently coarse grained and one fine grained by the McQuaid-Ehn test, have been heat treated so as to refine the grain and appear similar under the microscope, the steel that was originally coarse grained, machines more readily and gives lower impact values than the one that was fine grained — probably because the same characteristics which cause the inherent coarsening or refining are retained, and influence the impact values regardless of subsequent treatments.

Chemical analysis, of course, has an influence on machinability. Those elements which when added increase the toughness or impact also make machining more difficult.

Generally when steels are machined before final heat treatment, normalizing or annealing operations are given in order to put the grain or the constituents in the best condition for machinability. When the steels are to be machined *after* the final heat treatment, the problem is not so simple because the very characteristics which make machining difficult (that is, toughness or high impact values) are those which are usually desired in the finished product. Here deep hardening is an essential factor, for obviously the cutting edge should always be working in metal of uniform characteristics.

Claims for improved machinability are made by some steel producers by the manner in which the steels are resulphurized. It is their belief that the form in which the sulphur is added has an effect. More recently claims have also been made for improved machinability of steels containing lead.

Toolsteels

By Frank R. Palmer

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WRITING a summary on toolsteels, as of October, 1938, is a little like stopping a movie, and from a single frame, read the past, present and future! However there is one situation worthy of comment, and that is that too many in the audience are impatiently waiting for some great and dramatic episode to happen. The advent of high speed steel, and the coming of cemented carbides are good illustrations of these episodes — but they are so rare that one gets tired waiting for them. Although research should never cease

(Please turn to page 314)

Classification of American Toolsteels — I

Adapted from Tool Steels, by James P. Gill

General Purpose Carbon Toolsteels

Water hardening; low wear resistance; high warpage; no red hardness; shallow hardening

Carbon	Silicon	Manganese	Sulphur	Phosphorus	Vanadium	Common Uses
0.60-1.25 (a)	0.15-0.50	0.10-0.35	0.03 max.	0.03 max.	Note (b)	Almost universal; note (c)

(a) Usually subdivided by 0.10% steps; for instance 0.65-0.75%, 0.75-0.85%, etc.

(b) Plain carbon steels have no vanadium; carbon-vanadium tool steels may have from 0.08 to 0.40% vanadium, depending on grade.

(c) In lower carbon ranges the steels make shear blades, hammers, striking dies, rock drills. In medium ranges of carbon, the steels make chisels, smith's tools, dies, and cutters for machine tools. In the higher ranges of carbon are small cutters, wood workers' tools and cutlery.

Chromium-Vanadium or Low Chromium Toolsteels

(Substitutes for carbon tool steels)

Mostly water hardening; low wear resistance; high warpage; no red hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Vanadium	Remarks	
0.50-1.40	0.15-0.50	0.10-0.35	0.10-0.25	......	Chromium corrects tendency toward soft spots	
0.50-1.40	0.15-0.50	0.10-0.35	0.25-0.50	......	More intense hardness	
0.50-1.40	0.15-0.40	0.10-0.35	0.60-1.20	0.10-0.20	Water hardening	Very tough in low carbon ranges
0.50-1.40	0.15-0.40	0.40-0.60	0.60-1.20	0.10-0.20	Oil hardening	

High Carbon, Low Tungsten Tool and Die Steels

(Finishing tools for hard steels or non-ferrous alloys)

Oil hardening; medium wear resistance; medium toughness; low warpage; no red hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Tungsten	Vanadium (Optional)	Remarks	
0.90-1.10	0.20-0.40	0.15-0.30	......	1.00-1.50	......	Somewhat erratic in heat treatment	
1.15-1.25	0.20-0.40	0.15-0.30	......	1.75-2.50	0.10-0.25		
0.90-1.10	0.20-0.40	0.15-0.30	0.35-0.75	1.50-2.50	0.10-0.25	Water hardening	more dependable
1.15-1.30	0.20-0.40	0.15-0.30	0.35-0.75	1.50-2.50	0.10-0.25	Oil hardening	

Manganese Oil Hardening Die Steels ("Non-Deforming")

(General purpose tools and especially dies, punches and broaches)

Oil hardening; low wear resistance; medium toughness; low warpage; no red hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Tungsten	Molybdenum	Vanadium	Remarks
0.85-0.95	0.20-0.40	1.50-1.75	......	......	......	0.10-0.25	More subject to grain growth
0.85-1.00	0.20-0.40	1.15-1.45	0.30-0.60	0.30-0.60	......	0.10-0.25	Corrects above, but hardness is lower
0.85-1.00	0.20-0.40	1.35-1.65	......	......	0.20-0.35	0.10-0.25	Attains highest hardness
0.90-1.00	0.20-0.40	0.90-1.15	0.50-0.90	......	......	......	Least susceptible to hardening cracks

Tungsten Alloy Chisel and Punch Steels

(Oil hardening steels; shears and battering tools for cold metal; heading dies)

Medium wear resistance; high toughness; low warpage; medium red hardness; medium deep hardening

Carbon	Tungsten	Chromium	Vanadium	Silicon	Remarks
0.45-0.60	0.75-1.25	0.75-1.25	......	1.00-1.50	Good wear resistance but somewhat brittle
0.45-0.60	1.50-2.00	0.75-1.25	......	1.00-1.50	Higher tungsten improves wear resistance
0.45-0.60	1.00-1.75	0.50-1.00	......	......	Low silicon increases toughness 25%
0.40-0.55	1.75-2.25	0.75-1.25	0.10-0.30	......	Most popular analyses, tough and fine grained
0.55-0.65	1.75-2.25	0.75-1.25	0.10-0.30	......	

Tungsten Finishing Toolsteels and Drawing Dies

(Brittle but intensely hard and keen edges for cutting hard materials)

Water hardening; medium wear resistance; low toughness; high warpage; no red hardness; deep hardening

Carbon	Tungsten	Chromium	Remarks	
1.20-1.40	5.00-6.00	......	Slightly better wear resistance than lower tungsten	High movement; best for drawing dies that must be rehardened after wear
1.20-1.40	3.00-5.00	......	Slightly tougher than higher tungsten	
1.20-1.40	4.00-6.00	0.40-0.80	Chromium improves heat treatability and reduces volume change	
1.20-1.40	4.00-6.00	1.00-1.50		

Silicon-Manganese Punch and Chisel Steels

(A water hardening and inexpensive steel for cold cutting)

Medium wear resistance; medium toughness; medium warpage; medium hot hardness; medium deep hardening

Carbon	Silicon	Manganese	Chromium	Molybdenum	Vanadium	Remarks
0.50-0.60	1.80-2.20	0.60-0.90	......	......	......	Spring steel analysis; all high silicon steels liable to soft skin
0.60-0.75	1.70-2.25	0.70-0.90	......	......	......	More carbon gives higher hardness
0.50-0.60	1.75-2.25	0.70-0.90	0.20-0.35	......	0.15-0.30	Alloys increase hardenability and refine grain
0.50-0.60	1.75-2.25	0.70-0.90	......	0.40-0.60	......	Molybdenum greatly increases hardenability
0.50-0.60	0.75-1.25	0.35-0.60	0.20-0.40	0.40-0.60	......	Low silicon reduces brittleness and wear resistance

Classification of American Toolsteels — II

Adapted from Tool Steels, by James P. Gill

High Carbon, High Chromium Punch and Die Steels

(Durable rolls, mandrels, punches, dies and shears for cold work)

High wear resistance; low toughness; low warpage; high hot hardness; deep hardening, difficultly machinable

Carbon	Chromium	Vanadium	Molybdenum	Cobalt	Nickel	Remarks
			Oil Hardening Types ("Non-Deforming")			
2.25-2.45	12.00-14.00	......	......	......	......	
2.10-2.20	12.00-14.00	0.75-1.00	......	......	......	Somewhat tougher
2.15-2.25	12.00-14.00	......	......	......	0.50-0.75	Slightly air hardening; most difficult to machine
2.15-2.25	12.00-13.00	0.75-1.00	......	0.60-1.00	......	Slightly red hard
			Air Hardening Types (Tougher Than Above; and Deform Less in Hardening)			
1.40-1.50	12.00-13.00	......	0.50-0.60	3.00-4.00	......	Red hard properties. Good for cutting tools on non-ferrous materials
1.50-1.70	16.50-18.00	......	......	......	......	Liable to harden non-uniformly
1.50-1.60	12.00-13.00	......	0.80-1.00	......	......	
1.50-1.60	12.00-13.00	0.80-1.00	0.75-0.90	0.40-0.60	......	Vanadium imparts greater toughness
1.40-1.55	12.00-13.00	0.80-1.00	0.75-0.90	......	0.60-0.80	Most difficult to machine

Chromium Die Steels for Hot Work

(Gripper, bending and heading dies for light work up to 600° F.)

Air or oil hardening; medium wear resistance and toughness; low warpage; medium hot hardness; deep hardening

Carbon	Chromium	Molybdenum	Remarks
0.85-1.00	3.75-4.00	......	Usually quenched in light air blast
0.85-1.00	3.25-3.75	......	Lower chromium reduces cracks during oil quenching
0.65-0.75	3.75-4.25	......	Oil quenching (lower carbon) but not as rigid at 500° F.
0.85-1.00	3.75-4.25	0.40-0.60	Best air hardener

Tungsten Die Steels for Hot Work

(Blanking, forming, extrusion and casting dies to work up to 1100° F.)

Air or oil hardening; medium wear resistance; medium toughness; low warpage; high red hardness; deep hardening

Carbon	Tungsten	Chromium	Vanadium	Remarks
0.25-0.35	8.00-10.00	2.50-3.50	0.30-0.60	In most general use; serviceable up to 1000° F.
0.35-0.45	8.00-10.00	2.50-3.50	0.30-0.60	Higher carbon gives higher hardness
0.40-0.50	9.00-12.00	1.25-1.75	......	Chromium lowered to increase toughness
0.25-0.35	12.00-16.00	2.50-3.25	0.30-0.60	Increased tungsten raises serviceability to 1100° F. Hardenability and brittleness rises with carbon content
0.35-0.50	12.00-16.00	2.50-3.25	0.30-0.60	
0.50-0.60	12.00-16.00	2.50-3.25	0.30-0.60	
0.50-0.60	17.00-19.00	3.00-4.50	0.60-1.20	Low carbon, high speed steel

Tungsten-Chromium Steels for Hot Work and Die Casting Dies

Air or oil hardening; medium wear resistance; good toughness; low warpage; high red hardness; deep hardening

Carbon	Tungsten	Chromium	Vanadium	Molybdenum	Silicon	Remarks
0.40-0.50	6.50-7.50	6.50-7.50	0.20-0.60	......	0.30-0.80	Maximum alloy for hottest services (1000° F.)
0.35-0.45	5.50-6.50	5.00-6.00	......	......	0.30-0.80	Tougher
0.30-0.40	0.75-1.25	4.50-5.00	......	1.00-1.50	0.80-1.00	Less expensive substitute
0.35-0.40	......	4.50-5.00	......	1.00-1.50	0.80-1.00	Properties similar to steel above

High Speed Steels

(Cutting tools of all types; tools for severe hot work)

Air or oil hardening; high wear resistance; low toughness; low warpage; high red hardness; deep hardening

Carbon	Tungsten	Chromium	Vanadium	Molybdenum	Cobalt	Remarks
				Conventional Types		
0.55-0.75	17.00-19.00	3.50-4.50	0.75-1.25	......	......	Most used; brittleness and cutting properties vary directly with carbon content
0.55-0.75	19.00-21.00	3.75-4.50	0.75-1.25	......	......	Better cutting ability but more brittle
0.75-0.85	17.00-19.00	3.50-4.50	1.75-2.25	0.40-0.90	......	Best cutting ability; excellent for finishing cuts
0.55-0.75	13.00-15.00	3.50-4.50	1.75-2.25	......	......	Roughing tools; somewhat erratic in hardening
				Molybdenum High Speed Steel		
0.60-0.85	1.00-2.50	3.50-4.50	0.75-1.25	6.00-8.00	......	Less expensive; "strategic" alloying element used
0.70-0.90	......	3.50-4.50	1.75-2.50	6.00-9.00	......	Improved by high vanadium content
				Cobalt High Speed Steel		
0.65-0.80	17.00-19.00	3.50-4.50	0.75-1.25	......	3.50- 5.00	For cutting hard, gritty or tough materials
0.65-0.80	17.00-19.00	3.50-4.50	1.50-2.25	0.50-1.00	6.00- 9.00	Cutting ability varies as total alloy content
0.65-0.80	18.00-21.00	3.50-4.50	1.75-2.25	0.50-1.00	10.00-13.00	Maximum alloy to be forgeable
0.65-0.80	12.00-15.00	3.50-4.50	1.75-2.25	......	5.00- 8.00	Good service on special jobs

Toolsteels . . . . . for these major improvements, and toolsteel users should never cease to hope for their coming, much economic loss to the mechanical industries can result from doing nothing but wait in the meanwhile.

Current toolsteel metallurgy is literally crowded with small but significant developments which, taken together, are worth much more than any single great discovery. In the chemical composition, for instance, the steel maker continually finds opportunities for refinements and improvements which add measureably to the efficiency, the uniformity, the ease of handling, or the dependability of his products. Add to these the continuous development along the lines of "timbre" or "personality" and you have a veritable parade of progress which, like the motion picture film, scarcely changes at all from frame to frame, but travels long distances in a relatively short time.

Other undramatic but highly significant improvements are coming into the manner of selecting toolsteel. What difference does it make how good a steel is if the toolmaker cannot apply it to the proper jobs? In selecting steel for a certain tool, there are at least a dozen *wrong* choices for every *right* one.

How can the toolmaker avoid the trouble and expense that attends wrong choices? Until quite recently he had to resort to the costly trial and error method, or else send to the steel mill for a "toolsteel expert". It is most significant that many of the progressive manufacturers are now presenting catalogs that index the toolsteels under the head of uses, or in the form of diagrams to facilitate proper selection. No one will ever know what it costs industry to make improper or inaccurate choices of toolsteel. We do know, however, that these definite steps which have been taken to help the toolmaker in his choice of steels have met with outstanding success.

Still other important changes have come into the heat treatment of tools, not the least of which is control of hardening furnace atmosphere. One hears of instances where the productivity of tools has been increased as much as five times by simply adjusting a valve on the hardening furnace and thus getting the proper atmosphere! If this improvement had been wrought with some new and highly dramatized kind of steel, it would be heralded as a major achievement, but it is nonetheless real when done by merely turning a valve on the hardening furnace. Refinements are coming into the time element for heating toolsteel, and also into quenching procedures. There is no more fruitful field for study than that of flushing fixtures; here again the productivity of certain types of tools can be multiplied several times by simply installing a suitable fixture.

If one will but add together the cumulative benefits to be derived from the improvements in toolsteel, the greater accuracy in selecting the proper types, and the modern heat treating methods, it will require no gift of prophecy to foresee that progress in the immediate future is more likely to be achieved by the thoughtful application of materials and processes already at hand, than by sitting idly by waiting for the advent of some millennium.

Cemented Carbides

By Zay Jeffries
Chairman of Board, Carboloy Co., Inc.

IN THE FIELD of cemented carbides the most significant recent progress is on the steel cutting problem. Many complicated machine setups are being operated entirely with carbide tools. These to date have been confined largely to "precision" steel forgings in the automotive industries on which the amount of stock to be removed is held to a minimum. However, there has been some heavy "hogging" on other types of forgings. Experience based on these jobs indicates that the successful machining of steel is dependent, to a considerable extent, on correct tool design and application, including the proper methods of holding the tools.

In the past, the tendency has been to place emphasis on the cemented carbide itself rather than an exhaustive analysis of the tool design and its application. While it is of course true that the former consideration is an important factor, it has become increasingly apparent that several existing grades of cemented carbide are successful for steel cutting when correctly applied. This does not imply that improvement in tool materials in the future is an unimportant item. Grades have been developed during the past year by various suppliers that, when applied correctly, have resulted in considerably improved performance.

It may be of interest to note that during the past year grades of cemented carbide specifically developed for the machining of steel have been applied with excellent results on some of the newer alloy cast irons with low carbon. They are closer to steel than iron in certain cutting characteristics. For example, they have a tendency, like steel, to crater the tool. More

Analyses of S.A.E. Steels

Numerical designations and analyses approved as standard by Society of Automotive Engineers

Carbon Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.
1010	0.05-0.15	0.30-0.60	0.045	0.055
1015	0.10-0.20	0.30-0.60	0.045	0.055
X1015	0.10-0.20	0.70-1.00	0.045	0.055
1020	0.15-0.25	0.30-0.60	0.045	0.055
X1020	0.15-0.25	0.70-1.00	0.045	0.055
1025	0.20-0.30	0.30-0.60	0.045	0.055
X1025	0.20-0.30	0.70-1.00	0.045	0.055
1030	0.25-0.35	0.60-0.90	0.045	0.055
1035	0.30-0.40	0.60-0.90	0.045	0.055
1040	0.35-0.45	0.60-0.90	0.045	0.055
X1040	0.35-0.45	0.40-0.70	0.045	0.055
1045	0.40-0.50	0.60-0.90	0.045	0.055
X1045	0.40-0.50	0.40-0.70	0.045	0.055
1050	0.45-0.55	0.60-0.90	0.045	0.055
X1050	0.45-0.55	0.40-0.70	0.045	0.055
1055	0.50-0.60	0.60-0.90	0.040	0.055
X1055	0.50-0.60	0.90-1.20	0.040	0.055
1060	0.55-0.70	0.60-0.90	0.040	0.055
1065	0.60-0.75	0.60-0.90	0.040	0.055
X1065	0.60-0.75	0.90-1.20	0.040	0.055
1070	0.65-0.80	0.60-0.90	0.040	0.055
1075	0.70-0.85	0.60-0.90	0.040	0.055
1080	0.75-0.90	0.60-0.90	0.040	0.055
1085	0.80-0.95	0.60-0.90	0.040	0.055
1090	0.85-1.00	0.60-0.90	0.040	0.055
1095	0.90-1.05	0.25-0.50	0.040	0.055

Free Cutting Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Range	Sulphur Range
1112	0.08-0.16	0.60-0.90	0.09-0.13	0.10 -0.20
X1112	0.08-0.16	0.60-0.90	0.09-0.13	0.20 -0.30
1115	0.10-0.20	0.70-1.00	0.045 max.	0.075-0.15
1120	0.15-0.25	0.60-0.90	0.045 max.	0.075-0.15
X1314	0.10-0.20	1.00-1.30	0.045 max.	0.075-0.15
X1315	0.10-0.20	1.30-1.60	0.045 max.	0.075-0.15
X1330	0.25-0.35	1.35-1.65	0.045 max.	0.075-0.15
X1335	0.30-0.40	1.35-1.65	0.045 max.	0.075-0.15
X1340	0.35-0.45	1.35-1.65	0.045 max.	0.075-0.15

Manganese Steels

See Note (a) for Silicon Content

No.	Carbon	Manganese	Phosphorus	Sulphur
T1330	0.25-0.35	1.60-1.90	0.040 max.	0.050 max.
T1335	0.30-0.40	1.60-1.90	0.040 max.	0.050 max.
T1340	0.35-0.45	1.60-1.90	0.040 max.	0.050 max.
T1345	0.40-0.50	1.60-1.90	0.040 max.	0.050 max.
T1350	0.45-0.55	1.60-1.90	0.040 max.	0.050 max.

Nickel Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Nickel
2015	0.10-0.20	0.30-0.60	0.40-0.60
2115	0.10-0.20	0.30-0.60	1.25-1.75
2315	0.10-0.20	0.30-0.60	3.25-3.75
2320	0.15-0.25	0.30-0.60	3.25-3.75
2330	0.25-0.35	0.50-0.80	3.25-3.75
2335	0.30-0.40	0.50-0.80	3.25-3.75
2340	0.35-0.45	0.60-0.90	3.25-3.75
2345	0.40-0.50	0.60-0.90	3.25-3.75
2350	0.45-0.55	0.60-0.90	3.25-3.75
2515	0.10-0.20	0.30-0.60	4.75-5.25

Molybdenum Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

S.A.E. No.	Carbon	Manganese	Chromium	Nickel	Molybdenum
4130	0.25-0.35	0.50-0.80	0.50-0.80	....	0.15-0.25
X4130	0.25-0.35	0.40-0.60	0.80-1.10	....	0.15-0.25
4135	0.30-0.40	0.60-0.90	0.80-1.10	....	0.15-0.25
4140	0.35-0.45	0.60-0.90	0.80-1.10	....	0.15-0.25
4150	0.45-0.55	0.60-0.90	0.80-1.10	....	0.15-0.25
4320	0.15-0.25	0.40-0.70	0.30-0.60	1.65-2.00	0.20-0.30
4340	0.35-0.45	0.50-0.80	0.50-0.80	1.50-2.00	0.30-0.40
X4340	0.35-0.45	0.50-0.80	0.60-0.90	1.50-2.00	0.20-0.30
4615	0.10-0.20	0.40-0.70	....	1.65-2.00	0.20-0.30
4620	0.15-0.25	0.40-0.70	....	1.65-2.00	0.20-0.30
4640	0.35-0.45	0.50-0.80	....	1.65-2.00	0.20-0.30
4815	0.10-0.20	0.40-0.60	....	3.25-3.75	0.20-0.30
4820	0.15-0.25	0.40-0.60	....	3.25-3.75	0.20-0.30

Chromium Steels

See Note (a) for Silicon Content

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range
5120	0.15-0.25	0.30-0.60	0.040	0.050	0.60-0.90
5140	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10
5150	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10
52100	0.95-1.10	0.20-0.50	0.030	0.035	1.20-1.50

Nickel-Chromium Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Nickel	Chromium
3115	0.10-0.20	0.30-0.60	1.00-1.50	0.45-0.75
3120	0.15-0.25	0.30-0.60	1.00-1.50	0.45-0.75
3125	0.20-0.30	0.50-0.80	1.00-1.50	0.45-0.75
3130	0.25-0.35	0.50-0.80	1.00-1.50	0.45-0.75
3135	0.30-0.40	0.50-0.80	1.00-1.50	0.45-0.75
3140	0.35-0.45	0.60-0.90	1.00-1.50	0.45-0.75
X3140	0.35-0.45	0.60-0.90	1.00-1.50	0.60-0.90
3145	0.40-0.50	0.60-0.90	1.00-1.50	0.45-0.75
3150	0.45-0.55	0.60-0.90	1.00-1.50	0.45-0.75
3215	0.10-0.20	0.30-0.60	1.50-2.00	0.90-1.25
3220	0.15-0.25	0.30-0.60	1.50-2.00	0.90-1.25
3230	0.25-0.35	0.30-0.60	1.50-2.00	0.90-1.25
3240	0.35-0.45	0.30-0.60	1.50-2.00	0.90-1.25
3245	0.40-0.50	0.30-0.60	1.50-2.00	0.90-1.25
3250	0.45-0.55	0.30-0.60	1.50-2.00	0.90-1.25
3312	max. 0.17	0.30-0.60	3.25-3.75	1.25-1.75
3325	0.20-0.30	0.30-0.60	3.25-3.75	1.25-1.75
3335	0.30-0.40	0.30-0.60	3.25-3.75	1.25-1.75
3340	0.35-0.45	0.30-0.60	3.25-3.75	1.25-1.75
3415	0.10-0.20	0.30-0.60	2.75-3.25	0.60-0.95
3435	0.30-0.40	0.30-0.60	2.75-3.25	0.60-0.95
3450	0.45-0.55	0.30-0.60	2.75-3.25	0.60-0.95

Caution: Check with S.A.E. for possible modifications before making important commitments

Chromium-Vanadium Steels

See Notes (a) and (c) for Silicon, Phosphorus and Sulphur

S.A.E. No.	Carbon Range	Manganese Range	Chromium Range	Vanadium Minimum	Vanadium Desired
6115	0.10-0.20	0.30-0.60	0.80-1.10	0.15	0.18
6120	0.15-0.25	0.30-0.60	0.80-1.10	0.15	0.18
6125	0.20-0.30	0.60-0.90	0.80-1.10	0.15	0.18
6130	0.25-0.35	0.60-0.90	0.80-1.10	0.15	0.18
6135	0.30-0.40	0.60-0.90	0.80-1.10	0.15	0.18
6140	0.35-0.45	0.60-0.90	0.80-1.10	0.15	0.18
6145	0.40-0.50	0.60-0.90	0.80-1.10	0.15	0.18
6150	0.45-0.55	0.60-0.90	0.80-1.10	0.15	0.18
6195(c)	0.90-1.05	0.20-0.45	0.80-1.10	0.15	0.18

Tungsten Steels

See Notes (a) and (d) for Silicon, Phosphorus and Sulphur

No.	Carbon	Manganese	Chromium	Tungsten
71360	0.50-0.70	0.30 max.	3.00-4.00	12.00-15.00
71660	0.50-0.70	0.30 max.	3.00-4.00	15.00-18.00
7260	0.50-0.70	0.30 max.	0.50-1.00	1.50- 2.00

Silicon-Manganese Steels

See Note (b) for Phosphorus and Sulphur

No.	Carbon	Manganese	Silicon
9255	0.50-0.60	0.60-0.90	1.80-2.20
9260	0.55-0.65	0.60-0.90	1.80-2.20

Corrosion and Heat Resisting Alloys

See Note (e) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Chromium	Nickel
30905	0.08 max.	0.20-0.70	17.00-20.00	8.00-10.00
30915	0.09-0.20	0.20-0.70	17.00-20.00	8.00-10.00
51210	0.12 max.	0.60 max.	11.50-13.00	....
X51410	0.12 max.	0.60 max.	13.00-15.00	....
51335	0.25-0.40	0.60 max.	12.00-14.00	....
51510	0.12 max.	0.60 max.	14.00-16.00	....
51710	0.12 max.	0.60 max.	16.00-18.00	....

Notes to Tables of Chemical Composition

Note (a). Silicon range of all S.A.E. basic openhearth alloy steels shall be 0.15 to 0.30%. For electric furnace alloy steels and acid openhearth alloy steels, the silicon content shall be 0.15% minimum.

Note (b). Phosphorus and sulphur in all S.A.E. nickel steels, nickel-chromium steels, molybdenum steels and silicon-manganese steels shall be 0.040% max. and 0.050% max. respectively.

Note (c). Phosphorus in all S.A.E. chromium-vanadium steels shall be 0.040% max. except in No. 6195, which shall be 0.030% max. Sulphur in all S.A.E. chromium-vanadium steels shall be 0.050% max. except in No. 6195, which shall be 0.035% max.

Note (d). Phosphorus and sulphur in all S.A.E. tungsten steels shall be 0.035% and 0.040% max. respectively.

Note (e). Silicon shall be 0.50% max. except in alloys 30905 and 30915, which may be 0.75% max. Phosphorus shall be 0.030% max. in all corrosion and heat resisting alloys. Sulphur shall be 0.030% max. in all except in the free cutting alloy X51410, which shall be in the range 0.15 to 0.50%.

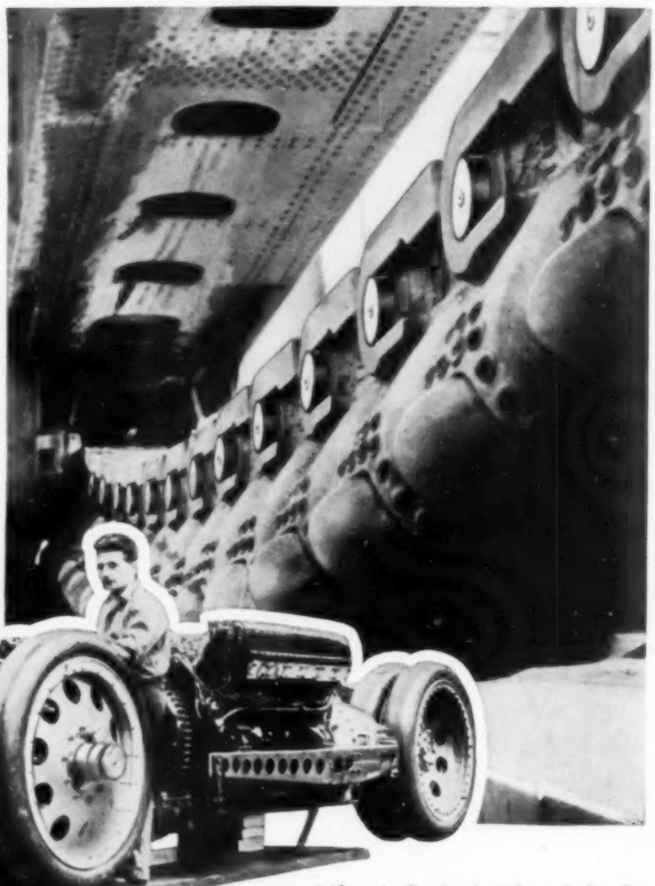
CAPTURING

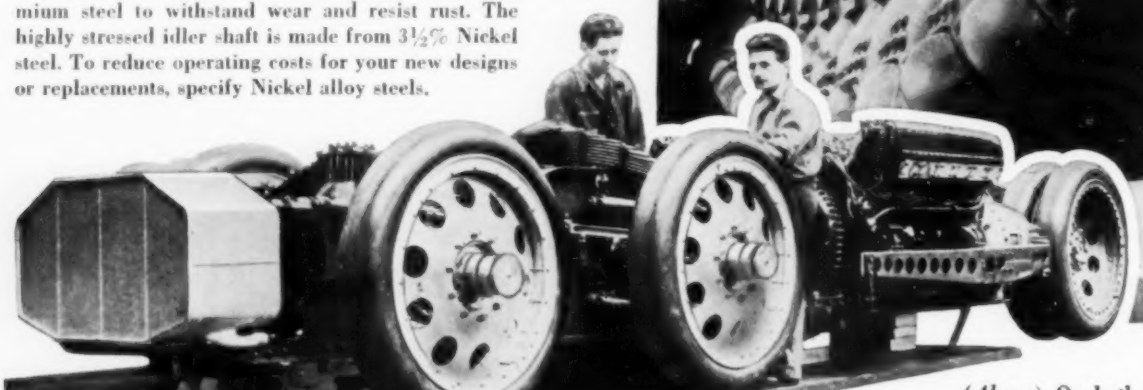
hidden gold, split-seconds and maintenance records with NICKEL ALLOY STEELS

You probably don't operate a 300 m.p.h. racing car, a passenger locomotive or a gold dredge. But you can learn from operating records of these three machines that tough, long-wearing Nickel alloy steels increase performance and decrease repair costs.

In your plant, on your machines, at those points where stress and wear and corrosion take heaviest toll, you can prove the ultimate economy of high strength/weight ratio Nickel alloy steels. Consultation regarding uses of Nickel is invited.

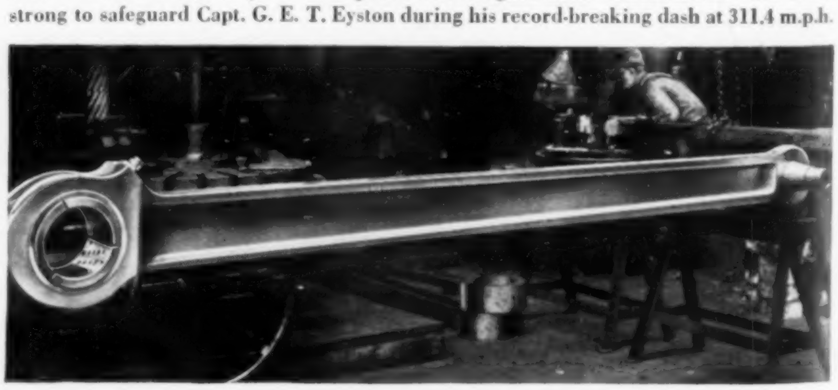
(Right) Even a gold mine isn't always profitable! Dredging gravel assaying only a few cents per ton means operating costs must be closely watched. To keep down upkeep, all bucket hinge pins on this Yuba dredge are forged from Nickel-chromium steel to withstand wear and resist rust. The highly stressed idler shaft is made from 3½% Nickel steel. To reduce operating costs for your new designs or replacements, specify Nickel alloy steels.





(Above) On both sides of the Atlantic, engineers have proved again and again that to automotive steels Nickel adds strength, toughness, resistance to shock and fatigue. From its 3% Nickel steel frame to Nickel steel nuts and bolts, every essential part of this English-built "Thunderbolt" was extra strong to safeguard Capt. G. E. T. Eyston during his record-breaking dash at 311.4 m.p.h.

(Right) Railroads have speeded up schedules and lowered operating costs by redesigning rotating and reciprocating engine parts and specifying Nickel alloy steels. New York Central tests proved that such rebalancing of mainline locomotives lessens rail pound at high speeds—and cuts track maintenance costs as much as 50%. You, too, may discover unexpected savings by using Nickel alloy steels.

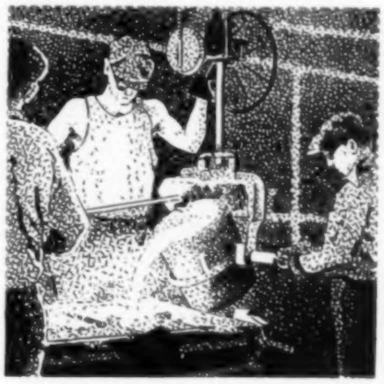


THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

of these harder irons are now in use than would be considered practical, were it not for the ability to machine them readily.

Among other new uses of the cemented carbides is the increased application in tipped gages. Higher standards of dimensional control in industry need longer life and greater continuous accuracy in gaging equipment. Cemented carbide is meeting this need.

The past year has also seen a broadening of the application to dies. Dies as large as 6 in. diameter are now in use and still larger ones seem to be practical.



Not even a brief review of the cemented carbide field would be complete without some mention of its use as a wear resistant material. The development here, though still in its early stages, is receiving more attention with each passing year. Certain machines may be markedly improved in output, quality of product and maintenance cost by using cemented carbide for small wearing parts, such as guides, rolls and cams.

Crushed diamonds embedded in cemented carbide or other alloys continue to be used for wheel dressers and small grinding tools.

Carbon Steel Castings

By Clyde B. Jenni
Metallurgist, General Steel Castings Corp.
Eddystone, Pa.

WHEN REVIEWING the metallurgical considerations leading to the improvement of carbon steel castings, one is impressed by the fact that their production has changed from a rule-of-thumb practice to a well regulated, scientifically controlled procedure. Applications of fundamental scientific principles and exercise of metallurgical control have resulted in improved products that give satisfactory service under severe operating conditions.

An important consideration leading to the improvement of castings is their design. The working knowledge of the designing engineer has been greatly increased by several recent contributions. Knowledge of shrinkage rules and the static physical properties is no longer sufficient. Dynamic properties, impact strength, endurance limits, creep properties, stress concentration and stress distribution are important considerations from the point of view of service life. Many foundry difficulties such as hot tears, shrinkage cavities, cracks at abrupt changes in section and at sharp angles, can be overcome by an application of sound design and an understanding of the principles of solidification of molten metal. Castings are now made of thinner sections than were thought practical several years ago and with closer tolerances for machining. The trend toward streamlining in design is in many cases sound practice in designing steel castings.

Most carbon steel castings are produced in electric furnaces, acid and basic, and in openhearth furnaces. Improved operating techniques based on metallurgical research has brought the basic openhearth process well to the fore as a producer. The intensive study of the physical chemistry of steel making has resulted in an improved quality of steel which is well suited for casting. As further information is gained on slag control, deoxidation practice, use of special deoxidizers, frequency, types and distribution of non-metallic inclusions, fluidity of steel, improved refractories, and general metallurgical control, continued improvements will be made in steel quality and further economies may be possible.

Considerable enlightenment on the application of aluminum as a deoxidizing and degasifying agent has been given to the producer of small carbon steel castings, especially of acid electric steel. Sound metal free from pinhole porosity is produced without suffering any ill effects on the physical properties.

The inherent properties of carbon steel castings, developed further by carefully controlled heat treatment, make this a unique engineering material, possessing strength to resist static loads and heavy dynamic stresses imposed by accelerated speeds, toughness to resist impact stresses, weldability, and a certain degree of corrosion resistance due to the surface condition imparted by the casting process.

Cooperation of the designing engineer, the metallurgist, and the foundryman has resulted in furthering the foundry art and science. More intricate shapes can be made and more rigid specifications met. Application of new facts or fundamentals more thoroughly understood will result in further advances.

Low Alloy Steel Castings

By C. E. Sims
Metallurgist, Battelle Memorial Institute
Columbus, Ohio

LOW alloy cast steels may be roughly divided as to use into two classes, one for structural parts and the other designed to be resistant to wear and abrasion. There can be, of course, no sharp distinction; many serve in both fields.

The present-day trend to save weight by using high strength materials in lighter sections has had a marked effect on the development of low alloy cast steels. Efforts now are being directed to producing steels with a yield strength 50% higher and an ultimate strength 40% higher than plain carbon steels, together with a ductility and impact resistance at least equal to the unalloyed steel.

A popular specification for such a steel calls for yield strength of 60,000 psi., ultimate of 90,000 psi., elongation of 22% in 2 in., and 45% reduction of area. Impact resistance is seldom specified, although an Izod impact of 30 to 50 ft-lb. is usually obtainable.

Cost is an important consideration, and for this reason the lower cost alloys and simpler heat treatments are favored. The ideal is a light alloy casting that will sell at the same price *per casting* as the bulkier carbon steel.

Manganese is the cheapest alloy and most potent hardener for steel, and for this reason the majority of the low alloy cast steels now contain between 1 and 2% manganese. The plain intermediate manganese steel used extensively in the past had several glaring metallurgical faults which have been corrected by the addition of another alloying agent. Plain manganese steel has, therefore, been superseded by such combinations as manganese with vanadium, titanium, aluminum, nickel, copper, molybdenum, or chromium. Other combinations with three alloys are used, as, for example, nickel-manganese-vanadium. One very successful steel contains low carbon (0.15 to 0.17%) with high manganese, copper, and silicon.

Vanadium, titanium, or aluminum in combination with manganese tends to refine the grain and reduce the tendency to air harden. Nickel or molybdenum with manganese refines the grain to a lesser extent and tends to increase the tendency to air hardening. Copper and chromium harden but do not affect grain size. Copper-containing steels are sometimes precipitation hardened.

Most any of these combinations can, by proper adjustment of composition and heat treatment, be made to pass the above specification. The cheapest heat treatment is a simple normalizing, and most of the structural cast steels have compositions designed to develop optimum properties when normalized. It is the usual practice to draw after normalizing. There is a reluctance (probably unfounded) on the part of consumers to use quenched and drawn castings for structural parts because of some possible injury during quenching. There is also the objection that quenching costs money and needs special equipment.

So much for the strong structural castings. Castings for resistance to wear and abrasion often have to serve as structural units as well and nearly always require some resistance to shock. The air hardening steels that develop high hardness tend to be brittle and are not favored for wear resistance. Nearly all steels for this purpose are quenched and drawn.

Chromium rules the field as an alloying element for wear resistant steels. It not only enables the necessary hardness to be attained, but the complex chromium carbide seems to provide special resistance to abrasion. Like manganese, however, chromium is seldom used alone. The long favored nickel-chromium combination is still popular, but quantities of steels with chromium and molybdenum, vanadium, or manganese are now being produced. Nickel-vanadium, nickel-molybdenum, and nickel-manganese are used for special purposes.

An interesting and promising cast steel for special types of wear resistance contains approximately 0.30 to 0.40% carbon and 3% chromium. It may be used in the unhardened condition and may contain 0.10 to 0.15% vanadium to increase toughness, or 0.30 to 0.40% molybdenum to overcome brittleness.

Grey Iron

By A. C. Denison
President Fulton Foundry & Machine Co., Cleveland

MOST outstanding of the developments in gray iron casting business in recent years is the awakening of the foundrymen themselves to the fact that gray iron can really be a dependable engineering material and that engineers are interested in it when the producer adopts scientific methods and puts his product under good metallurgical and technical control.

The truth of this statement is evidenced by the increasing employment of metallurgists and engineers in jobbing gray iron foundries, and

the constantly increasing use of better melting equipment and accurate instrumental controls for foundry operation. Among these items one notes automatic blast controls for cupolas that correct volume automatically for variations in temperature and barometric pressures, volumeters, new tuyere designs, sized coke to standardize combustion, automatic recording charts for metal temperature, rotary furnaces, forehearths, electric furnaces, sand controls.

Foundrymen are more generally realizing that gray iron properly manufactured has special properties of great engineering importance. Gray iron has good working values in modulus of elasticity, good practical values in resilience, outstanding properties to dampen vibration, and the valuable characteristic of crackless plasticity. These properties of gray iron are receiving growing recognition by engineers and the scientific awakening now evident in the foundry industry is putting engineering irons, made to definite A.S.T.M. specifications, on the market in most manufacturing centers.

Research metallurgists, in exploring regions in the ternary iron-carbon-silicon system that formerly blanked off the steel area from malleable and malleable from gray iron, have developed many new compositions, already in commercial use. Almost any point selected in this ternary system within a carbon range of 0.05 to 4.0% and a silicon range of 0.15 to 3.0%, indicates the base composition of some commercial material produced in a steel, gray iron, or malleable foundry.

Along with the scientific and metallurgical improvement incident to gray iron which has centered principally around the manufacture of high strength gray iron has come the heat treatment of these gray irons. They can be hardened and strengthened in this manner the same as special steels. During the last year especially we have seen engineers utilizing these practices in applications requiring great wear resistance. As is discussed at greater length in another section of this issue, the heat treatment may follow the usual procedure of quenching and drawing (which seems most practical for smaller parts) or the special procedure of flame hardening certain faces of larger castings.

Other factors of importance are the better understanding of the effects of alloys and heat treatment, and of the principles of control in all processes of manufacture. These are responsible for higher physical properties, and engineers therefore more generally utilize these modern gray irons in their designs.

Alloy Cast Irons

By Hyman Bornstein
Deere & Company, Moline, Ill.

ALLOY CAST IRON costs more than plain cast iron, yet each year we find proportionately more of it being used. This means that alloying elements must serve a useful and economic purpose in the field of iron castings.

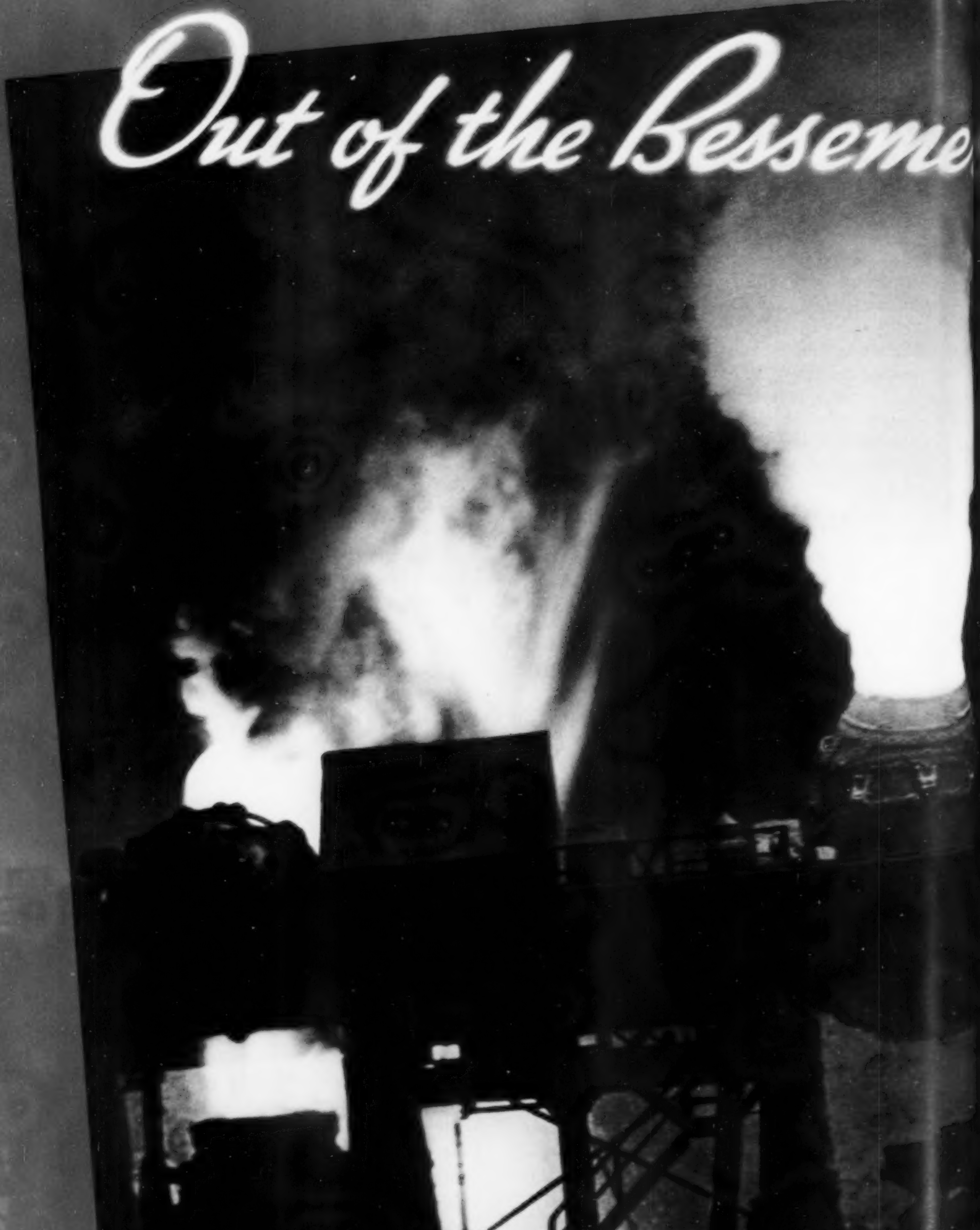
Just as in steel metallurgy, there is a choice in the selection of alloying elements to be used. There are many cases where a number of combinations of alloys can be employed to secure the desired results. So we find nickel, chromium, molybdenum, vanadium, copper, titanium, zirconium and even other elements used.

During the past year, due to business conditions, there have been determined efforts to reduce costs. Alloys cost money and so castings have been studied tc determine whether or not the alloys were really required. In some cases, changes were made in the alloy combinations used; but by and large, the alloys stayed in because they were needed to produce the physical properties desired. In the cast iron field today (more so than a few years ago) alloys are used because they are needed, rather than because someone had a notion to use an alloy cast iron. Plain (non-alloy) cast irons are being made with better qualities than ever before, and alloys are added when the limitations of plain iron have been reached.

More frequently gray iron castings are being heat treated (quenched and drawn) and in most cases this means the use of an alloy iron in order to get the high physical properties desired. One example is in the field of cylinder liners, which use alloy cast iron, and the tendency is to heat treat these castings to obtain maximum hardness and strength.

Alloys are also added to white and chilled iron castings in order to secure greater hardness, wear resistance, or toughness. The elements used and the amounts are determined by experiment to find the most economical method of obtaining the desired properties.

Selection of the range of composition requires study in order to choose a material which can be readily and economically produced. To obtain certain physical properties, one foundry, because of its particular foundry practices, may find it necessary to use alloying compositions which are quite different from those used in another foundry. For the optimum results, cooperation of the designer, metallurgist and foundryman is required.



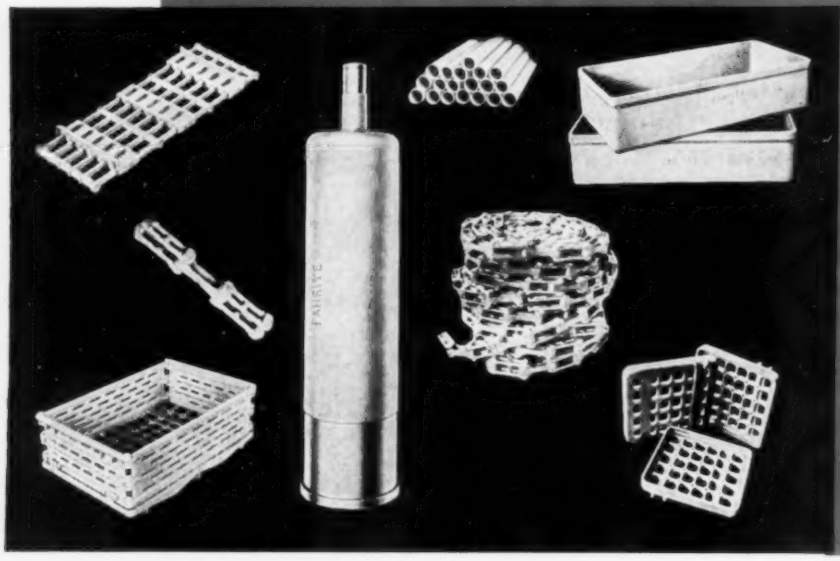
USS

HEAT AND CORROSION RESISTANT METALS

METAL PROGRESS OCTOBER, 1938

FAHRITE

HEAT AND CORROSION RESISTING ALLOY CASTINGS



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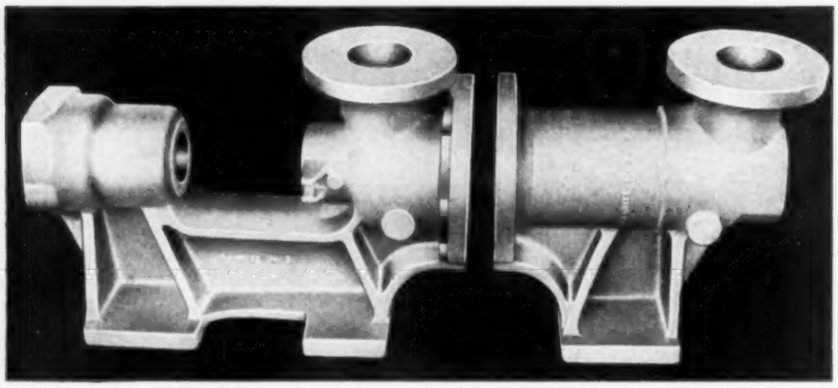
BOOTH A-216
NATIONAL METAL EXPOSITION
OCT. 17-21

Above. A few typical Fahrite heat-resisting applications.

Below. Fahrite corrosion-resisting castings for acid sludge pumps.



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THE OHIO STEEL FOUNDRY CO.
SPRINGFIELD, OHIO

Heat Resisting and Corrosion Resisting Metals

Expansion in Uses of Stainless Steels

By J. M. Schlendorf
Asst. Vice-President in Charge of Sales
Republic Steel Corp., Cleveland, Ohio

IN THE SHORT SPACE of a brief memorandum it is little more than possible to give a list of some of the important old uses and interesting new applications. Actually the uses are legion. Stainless now goes into almost every industry where metal is used. Experience also shows that a relatively small consumption one year in a certain obscure application frequently becomes a sizable consumption in the next year. Hence the prospect is for a continually increasing market for those extraordinary alloys commonly called stainless steels — even in view of the fact that the sales during the recession have been proportionately and gratifyingly higher than in the older lines.

Some outstanding features in the present market are listed below, alphabetically. In addition to these, mention should be made of the chemical and processing industries generally, where increased applications are becoming apparent. In these fields the question of contamination of the product by minute quantities of metal, dissolved from containers, is often of far more importance than any possible damage to the equipment itself.

Aircraft Industry — While for a number of years stainless steel has found quite extensive use in the aircraft industry, notably on applications for resistance to heat, such as exhaust stacks, collector rings and fire walls, together with other applications where resistance to corrosion is necessary, such as battery boxes, instrument parts, tie rods and fittings, the trend now is toward adoption for more general use. Widespread application is anticipated for structural parts because of the high tensile properties available on a product which can readily be spot welded without loss of strength and having such resistance to salt air and ordinary atmospheric conditions that no allowance whatsoever need be made for corrosion losses. This offers great possibilities for use in the navy and for seagoing commercial planes.

Architectural Applications — Another leading outlet for stainless steel, replacing nonferrous metals, is for interior and exterior applications in architecture. Exterior applications include store fronts, marquees and doors; interior applications include elevator cabs, hand railings, etched panels, and kick plates. Resistance of stainless sheet to the highly corrosive atmospheres of industrial centers and to salt air has exceeded expectations.

Automotive Industry — An increasing tonnage has been sold in the past few years for trim, and current reports indicate applications for 1939 will be extended. Steering wheel spokes are a relatively new application. The advantages of stainless over plated parts are readily apparent; snap-on trim of stainless strip is even com-

petitive with colored striping, painted by hand.

Beverages — With an eye to sanitation and long life, the beverage dispensing industry has recently adopted stainless steel for liners in bottle coolers and trim for the cabinets for soft drinks. In addition to the cabinets, stainless steel drums and containers are being used to ship syrup to the bottler.

Dairying — Since the substitution of stainless steel for non-ferrous metals in the dairy industry, a number of years ago, its increased use has been remarkable. It is now being used extensively for equipment such as milk holding tanks, pasteurizers, heat exchangers and — a very recent dairy application — milk irradiators. While white metal fittings are still being used in the dairy industry, these likewise are being replaced with stainless. Another development over the past two years has been the replacement of tinned bronze heat exchanger plates with stainless steel.

Distilling and Brewing — With the advent of repeal, a new field was opened and American brewers and distillers profited by the experience of Europe in utilizing stainless steel for various processing and transporting equipment.

Food Industry — Stainless steel of the 18-8 grade is replacing galvanized steel and non-ferrous metals for conveyors, tables and steam jacketed kettles in the meat and fish packing industries, as well as in the canning industry.

Government Power Projects — Valves, valve stems, rolls and tracks for roller gates for dams, grouting and miscellaneous applications are noteworthy.

Household Refrigeration and Electric Ranges — A most important use has been for evaporators for refrigeration units. A recent development is in connection with ice cube ejectors and trim for household refrigerators. Electric ranges utilize stainless for heating elements, covers and trim.

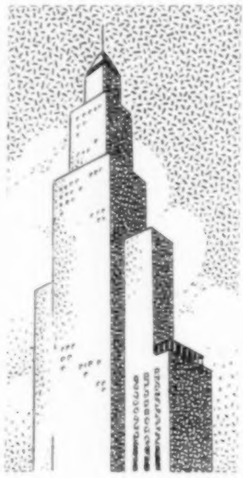
Institutional Equipment — There is an increasing demand for stainless steel for such items as flatware and hollow ware, tables, sinks, shelves, counters and utensils, steam table pans and bain-marie pots for the hotel and restaurant field. In hospitals may also be found bed pans, pus basins, solution basins and sponge bowls.

Oil Industry — The use of corrosion and heat resisting alloys has been greatly responsible for the high quality anti-knock gasoline available today. These constructional materials enable oil cracking processes to perform at higher temperatures and pressures than otherwise. Increased applications are constantly developing in this country.

Photographic Equipment — For this industry one of the highest corrosion resisting grades of stainless is being furnished. The applications are for development trays, film containers and processing equipment.

Textile Industry — In 1930 there was less than 25 tons of stainless steel used for dyeing, bleaching and other wet operations. By the end of 1937, more than 1000 tons was in daily use. The adoption of stainless steel has guaranteed true colors in dyeing and a substantial saving in bleaching costs.

Transportation — The availability of high tensile stainless steel has made possible the Budd high speed, light weight trains which are revolutionizing transportation.



18-8 and Its Modifications

By Russell Franks
Research Metallurgist
Union Carbide & Carbon Research Laboratories
Niagara Falls, N. Y.

EARLY in the development of the 18% chromium, 8% nickel steel, the late Dr. John A. Mathews predicted that while the metallurgy of these austenitic steels appeared simple because of the single constituent, this apparent simplicity might be the cause of considerable anxiety. Only a few years were required for this prediction to come true. The preliminary investigations of the 18-8 steels had shown that if they were cooled rapidly from temperatures in the range 1850 to 2200° F. the steels consisted entirely of austenite, and were among the most ductile and tough materials known to metal-

lurgists. In this condition they were also among the most corrosion resisting materials available. To chemists and chemical engineers it seemed as though their dream of finding a metal with the durability of stone had been realized, and almost immediately attempts were begun to develop and operate chemical processes that heretofore had not been considered feasible because of lack of equipment.

It cannot be doubted that in a very large number of these processes the 18-8 steel functioned well, but in other important instances failures occurred — for instance, when the 18-8 steel was used to resist corrosion either at moderately high temperature or after it had been held at moderately high temperatures during fabrication, such as in hot bending, forming, riveting and welding. Observations showed that when failure occurred the steel lost its metallic ring, and in some cases fell apart into a heap of individual grains.

After much experimentation it was found that the austenitic constituent partially transformed on heating in the range 750 to 1450° F., and the grain boundary areas became markedly less resistant to corrosion. It was decided that this was the result of carbide precipitation at the grain boundaries, which rendered the metal subject to intergranular corrosion. The first step taken to avoid the difficulty consisted of reducing the carbon content of the steels but this was soon found to be inadequate. The percentages of chromium and nickel were varied, and the same result was obtained.

Success was achieved by the addition of carbide forming elements, but of these only columbium and titanium were found to impart practical immunity to intergranular attack. The columbium addition is especially effective because the steels containing this metal can be used as welding rods and sufficient columbium can be retained in the welding metal to inhibit intergranular attack. The percentages of titanium that produce optimum resistance to intergranular corrosion are on the order of six times the carbon content, while with columbium it is advisable to have at least ten times as much columbium as carbon present if the metal is to be used under the influence of corrosion in the range 750 to 1450° F. (or six times if it is to be welded and used at temperatures up to about 600° F.). The columbium addition produces no serious effect on the resistance of the 18-8 steel to general corrosion, and if chemical service is involved it is to be preferred.

More recently the 18-8 steels have been found to be subject to other local types of corrosion known as "pitting" and "contact corrosion". These types of corrosion take place under wet conditions and in media that are acid. Pitting manifests itself by the development of small holes located at random in certain areas of the steel. Contact corrosion occurs when the 18-8 steel is in fairly tight contact with itself or other materials, and the attack may occur with or without simultaneous pitting. One of the important applications of the 18-8 steel in which pitting has occurred is in marine service when the parts are exposed to either stagnant or nonaërated sea water.

A good deal of work has been done on this problem, and encouraging results have been obtained by adding 2 to 4% molybdenum. Such steels have been found to be far superior to the plain 18-8 steels as far as pitting or contact corrosion is concerned. Addition of columbium to the 18-8 steels containing molybdenum has also yielded good results. It permits the steels to be welded without fear of intergranular corrosion, and also retards pitting and contact corrosion in welded sections.

The compositions of the 18-8 steels containing columbium and molybdenum must be changed slightly to secure good fabricating properties; for instance, the nickel content should be increased to give an austenitic steel. Additions of 1 to 2% manganese greatly improve hot fabricating properties and assist in welding. They also improve the general quality of the steel and add to, rather than detract from, their corrosion resistance.

Silicon is added to improve oxidation resistance at high temperatures. It helps in welding and for this purpose is generally present to the extent of about 0.50%. Silicon increases the fluidity of molten 18-8, and 1% is frequently added to obtain castings with good surfaces.

Selenium is added to enhance machinability; the usual percentages added being between 0.20 and 0.30.

From the standpoint of commercial usage these additions are the most important. The 18-8 steels have served industry well, but with these additions their utility has been greatly increased. So it will be seen that progress has been made in rendering them more acceptable to the consumer. Their requirements are likely to become more severe, and further modifications may be necessary to broaden the field of application of these almost indispensable steels.

Relative Corrodibility of Some Common Metals and Alloys

Compiled 1933 by Jerome Strauss, Vanadium Corp. of America

Nominal Composition

Class of Material	Carbon	Chromium	Nickel	Silicon	Copper		
Ingot iron or wrought iron	0.03				0.08		
Low C steel	0.10				0.08		
Low C copper steel	0.10				0.25		
Hot galvanized iron & steel							
Calorized iron & steel							
Grey cast iron	2.8 graphite, 0.7 combined carbon						
High silicon iron	0.60			14.25			
Nickel cast iron	3.30		3.50	1.50			
Chromium cast iron	2.50	25.00		2.00			
Ni-Cr-Cu cast iron	3.00	2.00	14.00	1.50	6.00		
Nickel steel: Low Ni	0.18		3.00				
High Ni	0.30		28.00				
Chromium steels: 5% Cr	0.15	5.00					
12% Cr	.10 max.	12.00					
17% Cr	.10 max.	17.00					
17% Cr, 4% Mo	.10 max.	17.00				Mo 4.0	
27% Cr	.50 max.	27.00					
Silcrome, (8% Cr, 3% Si)	0.45	8.25		3.50			
Stellite	3.0 max.	30.00				Co 55.0	W 15.0
Cr-Ni steels: 8-20	0.20	8.00	20.00				
18-8, 4% Mo	0.15	18.00	8.00			Mo 4.0	
18-8	0.10	18.00	8.00				
18-12	0.10	18.00	12.00				
18-35	.50 max.	18.00	35.00	1.00			
25-12	.25 max.	25.00	12.00				
26-24	.15 max.	26.00	24.00	3.00			
Commercially pure Ni			99.20				
Nickel alloys: Monel metal	0.15		67.50	0.50	28.50	Mn 1.50	
Nichrome, 60-15	0.12	15.00	60.00				
Inconel, 14% Cr		14.00	80.00			Fe 6.0	
80% Ni, 20% Cr		20.00	80.00				
Hastelloy		14.00	58.00			Mo 17	W 5.0
Commercially pure Cu					99.90		
Copper alloys: Red brass					85.00	Zn 15.0	
Tobin bronze					60.00	Zn 39.2	Sn .75
Phosphor bronze					95.00	Sn 5.0	Zn 1.5
Silicon bronze				3.00	95.00	Mn 1.0 or	{Sn .5
Aluminum bronze					90.00	Al 9.0	{Fe .5
Nickel silver			20.00		75.00	Zn 5.0	{Ni .5
Admiralty metal					70.00	Zn 29.0	Sn 1.0
Commercially pure Al						Al 99.20	
Commercially pure Sn						|	
Commercially pure Pb					0.06	Pb 99.90	

Atmospheres, Water, Oxidation Resistance (Max. Safe Temp. °F.), Foods

Class of Material	Atmospheres: Sea Shore	Atmospheres: Industrial	Water: Domestic	Water: Mine	Water: Sea	Water: Saline with H_2S	Water: Brackish with MCl	Water: Wet Steam	Oxidation: Oxidizing Gases	Oxidation: Reducing Fuel Gas	Oxidation: Sulphur Rich Gas	Fruit, Vegetable Juices	Dairy Products	Other Food Products
Ingot iron or wrought iron	P	P	P	P	PF	P	F	F				P	P	P
Low C steel	P	P	P	P	F	P	F	F				P	P	P
Low C copper steel	F	G	P	F	F	P	F	FG				P	P	P
Hot galvanized iron & steel	G	G	F	F	G	F	F					P	P	P
Calorized iron & steel	G	G	P	P	P				1650	1650	1650			
Grey cast iron	F	G	F	F	F							P	P	P
High silicon iron	E	E	E	G	E							G†		
Nickel cast iron	F	G	P	P	F									
Chromium cast iron	G	G	G	G	FG				1800	1800	1800			
Ni-Cr-Cu cast iron	G	G	G	G	G	F	F	G	1200	1200	1200	F		
Nickel steel: Low Ni	F	F	F	P	F							P	P	
High Ni	G	G	G	FG	E							F		
Chromium steels: 5% Cr	F	F	F	P	P	P	P	F	1200	1200	1200	P		
12% Cr	G	G	G	F	F		F	G	1400	1400	1400	G		G
17% Cr	G	G	G	G	G		G	G	1600	1600	1500	G	G	G
17% Cr, 4% Mo	G	G												
27% Cr	G	G	E	G	G		G	E	1900	1900	1800	E	G	E
Silcrome, (8% Cr, 3% Si)	G	G	F	F	F	F	F	F		1500		F		
Stellite	E	E	E	E	E	E	G	E	2000	2000		E	E	E
Cr-Ni steels: 8-20	G	G	G	G	G				1600	1600				
18-8, 4% Mo	E	G	E	G	G	E	E	E						
18-8	E	G	E	G	G	E	G	E	1550	1550	300 to 1300	G	E	E
18-12	E	G	E	G	G									
18-35	E	G	E	FG	G				1900	1900	1900	G		
25-12	E	G	E	G	G	E	G	E	2100			G	E	E
26-24	E	G	E	G	G	E	G	E	2100	2000		G	E	E
Commercially pure Ni	E	G	E	G	E	G			1300	2000	P	G	GE	GE
Nickel alloys: Monel metal	E	G	E	PE	E	G		E	900	2000	P	G	FE	FG
Nichrome, 60-15	G	G	E	G	G				1475 to 2100		P	G		
Inconel, 14% Cr	G	G		G	G				2000	2000		E	E	E
80% Ni, 20% Cr	G	G	E	G	G							G		
Hastelloy	E	E	E	G	E	E	E	E				E	G	G
Commercially pure Cu	G	G	G	FG	G							FG	P	F
Copper alloys: Red brass	G	G	FG	FG	G							FG	P	P
Tobin bronze	G	FG		F	G	F								
Phosphor bronze	G	FG		F	G							P	P	F
Silicon bronze	G	G		FG	G							G	P	
Aluminum bronze	G	G		FG	G							FG	P	
Nickel silver	G	G		G	G							G	P	
Admiralty metal	G	G		FG	G							FG		
Commercially pure Al	F	F	PG	P	F							G	G	G
Commercially pure Sn			E										G	G
Commercially pure Pb	G	G	PG	G	G							P	P	P

Acids (Moderate Concentration 5-15%), Alkalies, Salt Solutions (Medium Concentration), Hot Sulphite Liquor, Dye Liquor, Refinery Crudes (Below 400°F.)

Class of Material	HCl	H_2SO_4	HNO_3	Acetic	Phosphoric	Alkalies: 1 to 20% Sol.	Alkalies: Fused	NH_4Cl	$MgCl_2$	$MgSO_4$	Hot Sulphite Liquor	Dye Liquor	Crudes: Sweet	Crudes: Sour
Ingot iron or wrought iron	P	P	P	P	P	E		P	F	F			F	P
Low C steel	P	P	P	P	P	E		P	F	F	P		F	P
Low C copper steel	P	F	P	P	P	G		P	F	F	P		F	P
Hot galvanized iron & steel	P	P	P	P	P	F		P	P	PF				
Calorized iron & steel											P	F	FG	FG
Grey cast iron	P	P	P	P	P	E	F	P	P	P	P	P	F	
High silicon iron	F	E	E	G	G	E		G	G	G	P			
Nickel cast iron						E	FG				P	P	F	
Chromium cast iron														
Ni-Cr-Cu cast iron	F	F	P	G	G	G	G	F	F	F	F	F	G	G
Nickel steel: Low Ni	P	P	P	P		E	G	P	F	F				
High Ni	F	G	P	P		E	G	F	E	E				
Chromium steels: 5% Cr	P	P	P	P	P	G		P	P	F	P	P	G	G
12% Cr	P	P	G	G	F‡	E		G	G	G	P	F	E	
17% Cr	P	P	G	E‡	P	E		G	G	G	F	F	E	E
17% Cr, 4% Mo														
27% Cr	P	P	E	F	G	G		E	E	E	GE			
Silcrome, (8% Cr, 3% Si)	P	P	E	G		G						PG		
Stellite	F	G	E	G	E	E		E	E	E	G	G	E	E
Cr-Ni steels: 8-20	P	G	F	G	G	G	G				P		G	
18-8, 4% Mo	P		G	G	G	G		E	E	E	GE		E	E
18-8	P	F	G	G	G	E	G	FG	E	E	GE	F	E	E
18-12	P	F	G	G	F	G					G		E	E
18-35	P	G	P	P	F	G	G				P			
25-12	P	P	G	G	F	G	G	E	E	E	GE	G	E	
26-24	P	F	G	G	G	G	G	E	E	E	E	G	E	
Commercially pure Ni	G	G	P	G	G	E	E			G	P	G		
Nickel alloys: Monel metal	FG	G	P	G	G	E	G	E		G	P	E	F	
Nichrome, 60-15	F	F	F	G	G	G					P			
Inconel, 14% Cr														
80% Ni, 20% Cr	F	G	P	G	G	E								
Hastelloy	G	FG	G	G	E	E	G	G	G	G	E	G	G	G
Commercially pure Cu	F	FG	P	FG	FG	FG					G	FG		
Copper alloys: Red brass	P	FG	P	FG	FG	P					G	FG		
Tobin bronze	P	F	P	F	F	F					G	F	FG	
Phosphor bronze	P	FG	P	FG	FG	FG					G	FG		
Silicon bronze	F	G	P	G	G	FG	P				G	FG		
Aluminum bronze	P	FG	P	FG	FG	FG						FG	G	
Nickel silver	F	G	P	G	G	G						FG		
Admiralty metal	P	FG	P	FG	FG	P						FG		
Commercially pure Al	P	P	P	F	P	P					P	F		
Commercially pure Sn	P	P	P								P			
Commercially pure Pb	F	G	P	P	G	P	P					F		

E = Excellent; almost unlimited service
G = Good; will give good service
F = Fair; only to be used in temporary construction
P = Poor
FG = F to G PE = P to E PG = P to G
† E at low and P at high concentration
‡ Below 50°C

Decorative Effects
With Sheet

By Oscar B. Bach
Oscar B. Bach Studios, New York City

STAINLESS STEEL SHEET as a medium of decoration is possibly the most desirable of all metals, due to its flexibility, strength, endurance, and non-oxidation characteristics. Used as a wall decoration for exterior or interior, it may be laminated in extremely light gages to an inexpensive backing material, like plywood, asbestos composition, and similar products well known to architects and builders. It can then be treated for permanent color by an inexpensive method in any pattern or design, actually lower in price than many paints or lacquers. It can also be interestingly polished, as now generally done by various steel corporations, without any color, by changing the direction of the polishing stroke according to any design; one can then get beautiful effects through differences of reflection.

Light gage stainless steel also lends itself with equal economy to texture treatment, either alone or in combination with the above mentioned processes. The aesthetic and artistic effect so gotten would be considerably less expensive and faster in production than if attempted in other materials. If stainless steel in soft condition, in light gage like 0.013 to 0.009-in., is subjected to an embossing or coining technique, its hardness is increased to a considerable extent, and, if then treated for color, as for instance, in bronze, gold or black, its finish and relief become permanent. Such finishes on other metals, on the other hand, would change through oxidation and deterioration. Stainless steel would also, through increased surface hardness, excel any other material against attack through wear and tear. Such textures and color could have a similarity to stucco, wood, textiles, and many other desired variations. They could be most economically applied in the steel mills with inexpensive rollers, at the very end of the last cold roll.

There is still another process available for the development of texture, as well as color effect, by using various etching or sandblasting processes. But such techniques are not as economical as the ones already described.

There are almost unlimited possibilities in combining some of the above mentioned techniques, or all of them. Some examples can be seen in metropolitan New York, as, for instance, the main entrance doors to the Fulton Savings Bank in Brooklyn; the elevator doors in color treatment and relief in the Pennsylvania Hotel in New York; the escalators by the Otis Elevator Co. in the Pennsylvania Railroad Station in New York; and also in the Permanent Stainless Steel Exhibition at the Procurement Division Building, in Washington, D. C. It is not to be inferred, of course, that the notable applications are so limited — the facts are quite otherwise, and uses of the material are bound to increase.

Medium Chromium Steel
5 to 15% Cr

By H. D. Newell
Chief Metallurgist
Babcock & Wilcox Tube Co., Beaver Falls, Pa.

TEN YEARS AGO, the refinery or power plant engineer had a choice between the carbon steels, the S.A.E. steels and the 18-8 stainless. (The 12% Cr type, in cutlery and low carbon grades, found only minor application.) For operating conditions in the 800 to 1200° F. range the 18-8 was economical or requisite only in special cases. The low alloy steels were lacking in corrosion resistance. Hence the development of medium chromium steels which are economical as to first cost, and have sufficiently good resistance to corrosion, oxidation and stress at elevated temperature.

Dixon made the first systematic investigation of these steels in oil refinery service. The modification of the 4 to 6% chromium steel containing 0.45 to 0.65% molybdenum, because of its freedom from embrittlement and its good strength, has now become more or less the standard alloy of the 5% chromium type. The plain 5% chromium steel first used is now practically obsolete, and the alloy with 0.75 to 1.25% tungsten is mainly used in valve parts. Thousands of tons of these steels have been used by the refining industry in the past eight years in still tubes, piping, heat exchanger tubes, valves and valve parts, header castings and bubble caps. Following this trend, the power industry has used the alloy extensively for superheater tubes and headers. Some has been used in chemical processes where corrosion requirements are not unduly severe.

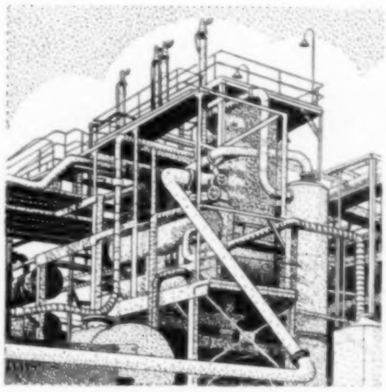
Other modifications of the 5% chromium type include those containing titanium or columbium for improving resistance toward scaling

The A-B-C of Corrosion and Heat Resisting Steels

Arrangement due to F. R. Palmer. Adapted from The Book of Stainless Steels, Second Edition

Group A (Martensitic)	Group B (Ferritic)	Group C (Austenitic)
Chemical Analysis Chromium less than about 16%; carbon less than about 0.40%. May contain small percentages of tungsten, copper, nickel, silicon, columbium, aluminum, and more frequently molybdenum. Group is magnetic.	Chromium more than about 16%; carbon quite low, but can increase as chromium goes up. May contain small percentages of copper, nickel, silicon, molybdenum, tungsten, nitrogen. This group is magnetic.	Contains enough nickel to make steel austenitic and non-magnetic. They usually contain twice as much chromium as nickel or vice versa; total alloy content at least 26%. Carbon quite low. (Manganese sometimes substituted for nickel, in part.)
Heat Treatment Respond to hardening and tempering. Resulting physical properties depend on chemical analysis (principally carbon content).	Do not respond. 18% chromium toughened by long anneal at more than 1400° F., and air cooling. Avoid decarburizing the skin. 25% chromium gets best strength and toughness by rapid cooling from 1650°.	Do not respond to hardening by heat treatment. Must be rapidly cooled from soaking heat at 1900 to 2150° F. to retain austenitic structure free of carbides. (Brinell 140 to 170).
Toughness Are structurally dependable. After tempering are not brittle in notched sections or under impact.	Laminated structure, from coarse ferrite in ingot, causes low impact values, but proper rolling and heating gives adequate toughness in rods, bars, and sheets. Structure is refined by nitrogen.	Extremely tough at all temperatures down to liquid air. Dependable against shock except when corroded at grain boundaries (a preventable condition).
Grain Growth and Structural Changes at High Temperatures Not subject to excessive grain growth. Thoroughly dependable for supporting any load or shock within their carrying capacity up to 1400° F. Brittleness in plain chromium steels when cooled after long heating is avoided by addition of molybdenum.	The chromium-irons low in carbon and those high in silicon or aluminum (when cold worked) are subject to excessive grain growth, especially above 1900° F. Grain growth reduced by nitrogen. Long service at 800 to 950° F. makes them brittle when cold, although they are not brittle at working temperatures.	Alloys near the austenite-martensite border line tend to precipitate carbides at grain boundaries during service at 800 to 1600° F., losing some toughness and becoming susceptible to intergranular attack. This is controlled by very low carbon, by titanium or columbium, by increasing the chromium and nickel, or by prior "stabilization."
Strength at Elevated Temperatures Much better than straight carbon steel for temperatures up to 1000 or 1200° F. Retain tensile properties up to 750° F.	Heat resisting varieties quite tough at temperatures up to 1600° F. Superior in ductility to Group C but not in creep resistance.	Have high creep strength up to 1200° F. which is enhanced by tungsten or molybdenum. Toughness impaired in non-stabilized alloys by service at 800 to 1600° F.
Hot Working Qualities Readily forged, pierced, or rolled at 2000 to 1700° F. Preheat and soak stock at 1600° F. Plain chromium alloys air harden on cooling.	May be forged, rolled, or pierced. Should be heated quickly. Forge from 2200° F. down to 1750° F. On last heat continue cold working to 1400° F. to refine grain. Alloys do not air harden.	May be forged, rolled, or pierced. Preheat and soak at 1600° F., heat quickly to 2200° F., forge down to 1850° F. Hot short range: 1800 to 1300° F. Alloys do not air harden.
Cold Working Qualities Low carbon varieties can be easily cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn.	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn, especially when warm (300 to 500° F.).	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn. Work-harden twice as rapidly as Groups A and B.
Machinability Machine satisfactorily with properly designed tools when heat treated to 200 to 250 Brinell. Free-cutting grade contains complex sulphides or selenium.	Machine satisfactorily with properly designed tools. Cold working and high sulphur or selenium improve machinability.	Most difficult of all even with super high speed and carbide tools. Use sharp tools having greater top rake than usual, and cut continually. Free-cutting grade contains selenium and phosphorus.
Riveting Make excellent cold rivets. Air hardening, plain steels not recommended for hot rivets driven above 1500° F.	Extra precautions required to avoid brittle rivets. Conical heads should be cold upset on ground bars; rivets driven at 1425° F. into chamfered holes.	Excellent for either hot or cold rivets. Hot rivets may be driven at a high temperature (1900° F.).
Welding Properties Preheated parts can be welded with gas, electric arc, or resistance. Anneal immediately before weld air hardens. Little grain growth. Columbium or aluminum increases ductility of welds.	Can be welded. Anneal at 1450° F. to reduce embrittlement alongside weld. Those metals subject to grain growth are brittle adjacent to the weld. — Those metals not subject to grain growth yield satisfactory welds.	Can be welded with gas, electric arc, or resistance, if carburization is avoided. Weld does not air harden and is very tough. Only the relatively low carbon or "stabilized" metal should be welded if article must resist corroding media.
Corrosion Resistance Increases with chromium content; inferior to Groups B and C. Resists weather, water, steam, and mild corrodents when chromium is 11.5% or more. If carbon is relatively high, metal must be hardened and tempered (below 1000° F.).	Possess corrosion resisting properties superior to Group A; increases with chromium content. Especially good for nitric and other oxidizing acids.	Corrosion resistance depends largely upon total alloy content. Resists nearly all corrodents measurably better than Groups A and B; especially good for organic acids. Severe pitting may occur in stagnant chloride solutions under particles of foreign matter and along faying surfaces.
Scale Resistance Increases with chromium content. Generally useful for continuous temperatures up to 1200° F., and in some services up to 1500° F.	Superior to Group A, especially when chromium is above 25%; then resist reducing atmospheres up to 2100° F., oxidizing up to melting points, and sulphur gases up to 1800° F.	Excellent where combination of high temperature and corrrosion is to be met. High chromium, low nickel alloys required to resist sulphurous gases. Addition of 2 to 3% silicon markedly improves scale resistance.

and to reduce the hardenability, thus facilitating welded fabrication. Other modifications under development are those containing silicon or silicon and aluminum, added mainly for the purpose of improving resistance toward scaling and corrosion. It is too early to predict their usefulness or reliability in relation to the standard 5% chromium with molybdenum, but they are being watched with interest, especially as silicon and aluminum furnish an inexpensive means of improving surface stability. Yields and quality during manufacture have given concern in modified alloys containing titanium, columbium and aluminum, and this is being studied.



In the higher chromium alloys approaching the stainless type is a 7% chromium-molybdenum-silicon alloy now undergoing development. 9% chromium, 1.25% molybdenum steel has seen several years' service in refineries and is now being applied for steam superheater construction, especially for marine boilers.

Of the stainless grades — that is, those over 11% chromium — a low carbon variety of 12% chromium steel with or without molybdenum is being used for railroad car construction where a high strength and resistance to atmospheric corrosion is required. It is especially useful for coal cars where seepage and acidic conditions are prevalent. Free machining grades of this, containing zirconium, selenium, phosphorus, sulphur or molybdenum, have been marketed for mechanical parts subjected to production machining operations. Also available are 12% chromium steels with molybdenum, silicon, copper or aluminum, the latter being a non-hardening alloy used for welded construction. Titanium and columbium additions have also been employed for this purpose. A steel containing 12% chromium and 3% tungsten has been used in petroleum refineries for tubes handling severely corrosive oils.

A steel with 15 to 16% chromium has been used for pressure vessel and nozzle linings. This form is preferred to the usual 18% chromium grade because of its better welding characteristics and relative freedom from secondary embrittlement after long heating in the range 800 to 1000° F.

Of singular interest during this developmental period is the place molybdenum has made for itself as a conjunctional alloying element with chromium in the intermediate alloys for elevated temperature uses. It is useful for improving creep strength and for suppressing tendencies toward embrittlement, and consequently is nearly always present with chromium irrespective of whether or not other elements such as silicon, aluminum, titanium or columbium are added for specific improvements.

Development continues in the research laboratories of steel producers. Chemical or process engineers are testing the new materials on a plant scale, which is preferable, or by hanging specimens at various locations in apparatus to determine corrosion rates, scaling, stability, the mechanical properties, and so on. Further work and service experience will eventually lead to a simplification or reduction of the number of alloys and a better understanding of their specific usefulness. Refinery engineers are already requesting economical steels of good strength for hydrogenation, de-hydrogenation, polymerization and high temperature cracking operations at temperature levels which are rapidly increasing. Economy of operation and maintenance, with increased quality of product, are assured when equipment is made of the alloy steels available today. Improvement in existing alloys and extension of their applications may be expected in the future.

Corrosion Resistant Castings

By Fred Grotts
Vice-President, Chicago Steel Foundry Co.
Chicago, Ill.

WHILE the number of metallic alloys, ferrous and non-ferrous, that have been put to use to combat corrosion is almost as large as the infinite aspects of the corrosion problem, the amount of alloys of the 18-8 family is undoubtedly the largest now being regularly cast.

The demand for stainless steel of the 18% chromium, 8% nickel variety is very interesting, interesting because of the increase in its use and variety of its applications. These applications

can be linked with almost every branch of industry since corrosion seems to be a factor that enters into almost every design.

Corrosion resistant and stainless steels fill a long felt need. The designing engineer has been plagued with the difficulty of producing designs that would retain their physical properties when exposed to strong corroding acids (such as sulphuric, nitric and hydrochloric), and he has turned to the stainless steels with relief. In the ramifications that result in the production of motor fuels and lubricants, he has found it necessary to resort to special materials for valves and connections because of the use of various acids necessary in their production and refinement. In other fields, the amount of corrosion of common metals is not enough to damage the equipment, but high corrosion resistance is necessary lest the metallic corrosion product contaminate (or even ruin) the substances being manufactured.

Again do we find it necessary to make use of these relatively new alloys when the essential parts are exposed to corrosive gases such as hydrogen sulphide, sulphur dioxide or chlorine, even sometimes in very dilute concentrations. These gases are reaction products encountered in the ever-increasing manufacture of new materials for building, clothing, paper making — in fact, practically all new developments in industry are requiring some type of stainless steel.

An example striking close to the man in the street has been the use of 18-8 for store fronts and various ornamental castings. Owing to the ease of casting this analysis, the field is practically unlimited. Another odd but important application is in cemeteries for grave markers.

Streamlined trains and airplanes, as well as speed boats and automobiles are increasing their requirements for rolled and cast 18-8, as its remarkable performance and resistance to atmospheric corrosion make it a necessary part of modern and future design.

For some special applications, research has proven that this analysis has very high impact properties at 300° below zero. Observed tests show Charpy impact values of 50 ft-lb. at this low temperature.

New metallurgical developments have been able to control the important property of machinability. Some analyses are very hard to machine because of spontaneous hardening due to cold working; therefore, a new technique that increases machinability will tend to increase the field for castings.

Extensive welding research has further proven the merits of adding elements such as columbium to prevent carbide precipitation and associated troubles.

Molybdenum in amounts up to 3% is valuable, as it increases the resistance to sulphuric acid and also performs another important function in that it unites readily with carbon and reduces the chromium content of the carbides. It also probably slows down the rate of diffusion and brings about a less dangerous precipitation of carbon, away from the grain boundaries.

The application of higher chromium and nickel analyses, such as 25-13 is not so great as the lower series; still in jobs requiring extra corrosion resistance it certainly is worth while.

It is very apparent that the field for this type of material is increasing rapidly. It seems that no sooner is it used for a new design, than another shows up requiring it. Many difficulties have been met, such as with welding, but in every case research has applied itself and the difficulty has been solved, with the result, in many cases, of a new and better material.

Heat Resisting Castings
Up to 35% Nickel

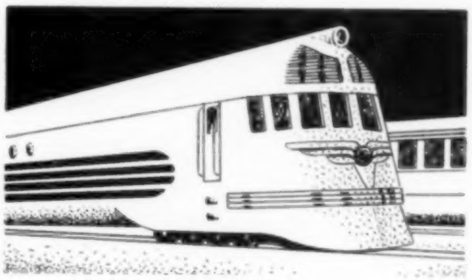
By R. J. Wilcox
Chief Metallurgist
Michigan Steel Casting Co., Detroit

IT IS OF INTEREST to note that while a decline in tonnage produced has paralleled the general business trend, new applications have become increasingly diversified and new industrial requirements are demanding higher degrees of operating performance from alloy cast parts. Controlled atmosphere furnaces, higher temperatures of operation, new types of heat treating salt baths, have all increased the severity of demands upon heat resisting castings. The 35% nickel, 15% chromium type of alloy continues to be favored for construction demanding the greatest strength at elevated temperatures. Atmospheric conditions of operation of course alter the degree of surface stability of the alloy parts; in certain types of reducing atmospheres we continue to find the higher chromium alloys such as the 24% chromium, 12% nickel, the 29% chromium, 9% nickel, and the 25% chromium, 20% nickel.

Engineering skill and ingenuity have also produced new types of construction as illustrated by the modern conveyor roll, new

designs in chain and chain belt, trays, and other heat treating equipment. In order to minimize operating failures, control of composition, melting and refining operations, molding and pouring conditions have become more and more exact. Both acid and basic melting furnaces are being used with equally good results, each practice having its own advantages and disadvantages. Much attention is being given to refining and deoxidation practices with relation to dissolved gases and the production of clean, fluid metal.

Of particular interest is the centrifugal casting process which by now has established its position in the production of chemical piping, conveyor rolls and many tubular products. In addition to the conventional types of arc and gas welding we find that flash welding is being used to a very large extent in the production of sound, strong joints. Conveyor rolls with flash welded trunnion members produce a highly dependable unit, many of which are operating continuously at 2050° F. It may be predicted that the field of usefulness of this centrifugal product will be extended.



In organizational work it is of interest to note the formation of the Alloy Casting Research Institute, a group of producers financing a joint research into the heat resisting and corrosion resisting alloys. The work of the Institute has been in progress for about a year at Battelle Memorial Institute. It is anticipated that standardization and agreement on the properties of the conventional alloys as well as major developments will be forthcoming.

Heat Resisting Castings
38 to 70% Nickel

By H. H. Harris
President
General Alloys Co., Boston, Mass.

BECAUSE nickel and chromium are basically heat and corrosion resisting metals the high alloys which use nickel as a base rather than iron are inherently heat resisting alloys as distinct from "doctored iron". Nickel unalloyed has high ductility, resistance to oxidation and carbon penetration, to structural changes in high temperature service, and to heat fatigue. Chromium, iron and carbon added to nickel add stiffness, strength and hardness, and high nickel-chromium alloys extending from 68% nickel, 18% chromium down to 35% nickel, 15% chromium, therefore, comprise the great bulk of carburizing containers, conveyors, trays, muffles and other fixtures exposed to heat in metallurgical furnaces.

At about 35% nickel, 15% chromium, however, the alloys are subject to microstructural changes within the temperature ranges at which they are commonly used. Such microstructural transformations are a potent cause of trouble. The higher nickel-chromium alloys are also resistant to "heat fatigue" (breakdown due to the repeated stresses of heating and cooling) and embrittlement by carbon penetration. Since almost all failures of alloy parts come from heat fatigue rather than from uniform exposure, the practical criterion for evaluating them should be "How long will the material withstand intermittent heating and cooling without cracking?" The stresses imposed on most alloy by contact of cold charges on hot alloy parts, effect of irregular temperatures in the furnace and variable sections in the same piece — all of these add to a far greater total in most instances than the stresses produced by the load which is carried.

Recent developments in the high nickel-chromium series are primarily the addition and control of secondary ingredients for modifications in physical properties for special conditions. For example, in roller rails recently developed, there are three grades of 38-18 each with small quantities of secondary ingredients, such as tungsten, aluminum, molybdenum, manganese, zirconium, or silicon. The shell of the rail of ¼-in. section, subject to considerable heating strains, is of a relatively ductile 38-18 base alloy. Bearings are hard, wear resistant 38-18 base alloy and the rollers are of a similar softer 38-18, developed to wear against the hard bearing. It is believed that this use of various modifications in a single mechanism will become quite common.

From recent improvements in methods of pressure casting have come much lighter wall

(Please turn to Page 346)

Properties of the Principal Cr-Fe Alloys

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Chemical composition							
Chromium	1.75 to 2.25	4 to 6	8 to 10	12 to 14	13 to 14	16 to 18	25 to 30
Nickel	(0.5 Mo)	—	(1.5 Mo)	—	—	—	—
Si and Mn (max.)	0.50	0.50	0.50	0.50	0.55	0.50	0.50
Carbon	0.15 max.	0.10 to 0.20	0.15 max.	0.10 max.	0.30 to 0.40	0.10±	0.10±
Specific gravity							
Lb. per cu. in.	—	0.280	0.282	0.276	0.278	0.273	0.270
(Mild steel = 1.00)	—	0.99	1.00	0.97	0.98	0.96	0.95
Electrical resistance at 70°F							
Microhms per cm.³	—	—	—	57	60	59	67
(Mild steel = 1.00)	—	—	—	5.2	5.5	5.4	6.1
Melting range, °F.							
Top	—	2800	—	2790	2750	2750	2750
Bottom	—	2760	—	2750	2580	2710	2710
Structure (normal)	Pearlitic	Pearlitic	Martensitic	Martensitic or Ferritic	Martensitic	Ferritic	Ferritic
Magnetism							
Ferromagnetic	Yes	Yes	—	Yes	Yes	Yes	Yes
Permeability: As annealed	—	—	—	—	—	—	—
Permeability: Cold worked 10%	—	—	—	—	—	—	—
Specific heat							
Cgs. units, 0 to 100°C.	—	0.11	—	0.11	0.117	0.11	0.11
(Mild steel = 1.00)	—	1.0	—	1.0	1.1	1.0	1.0
Thermal conductivity							
*C.g.s. units at 100°C.	—	0.0874	—	0.0595	0.05	0.0583	0.0500
(Mild steel = 1.00)	—	0.73	—	0.50	0.42	0.49	0.42
C.g.s. units at 500°C.	—	0.0803	—	0.0686	—	0.0624	0.0583
Thermal expansion per °F. x 1,000,000							
From 32 to 212°F.	—	6.1	6.29	6.1	5.7	6.0	5.9
(Mild steel = 1.00)	—	0.93	0.95	0.93	0.87	0.91	0.90
From 32 to 932°F.	—	7.2	7.00	6.7	6.6	6.7	6.3

Mechanical Properties at Room Temperature	2% Cr Annealed	5% Cr Annealed	5% Cr †Heat Treated	9% Cr Annealed	12% Cr Annealed	12% Cr †Heat Treated	Cutlery Annealed	Cutlery ††Heat Treated	17% Cr Annealed	17% Cr Cold Worked (Wire)	27% Cr Annealed	27% Cr Cold Worked (Wire)
Ultimate strength, 1000 psi.	60 to 70	66	115	75 to 87	65	125	100	230 to 260	75	100 to 190	75 to 95	85 to 175
Yield point, 1000 psi.	30 to 45	27	103	35 to 45	35	100	65	200 to 220	40	—	50 to 60	55 to 155
Elastic modulus, 10^6 psi.	—	—	—	—	28	—	—	—	29	—	—	—
Elongation, % in 2 in.	40 to 30	38	20	40 to 30	35	20	27	8 to 2	27	—	30 to 20	—
in 10 in.	—	—	—	—	—	—	—	—	—	25 to 2	—	25 to 2
Reduction of area, %	—	76	66	—	65	60	59	20 to 2	55	40 to 20	60 to 50	55 to 25
Impact, ft-lb., Charpy	35 to 65	—	—	35 to 60	—	75	—	—	—	—	—	—
Izod	—	80	75	—	80	—	—	—	8 to 25	—	—	—
Fatigue endurance limit, 1000 psi.	—	—	—	—	—	—	—	—	48	—	50	—
Corresponding ultimate strength									76		78	
Hardness, Brinell	130 to 160	136	250	145 to 180	140	230	170	480	175	185 to 270	160 to 190	150 to 250
Rockwell	—	B-75	C-24	—	B-76	C-22	—	C-56	B-85	B-90 to 105	B-80 to 90	C-0 to 25
Erichsen value, mm.	—	—	—	—	—	—	—	—	7 to 9	—	—	—

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	11,400	7,000	11,600	13,000		8.500	—
1100	5,650	—	6,950	5,200		5,200	—
1200	3,150	—	2,300	2,100		2,100	1,600
1350	—	—	—	1,400		1,200	400
Scaling temp., °F.		1200	1200	1300	1750	1550	2100
Initial forging temp., °F.		2100	—	2100	2000	2000	2200
Finishing temp., °F.		About 1400	—	max. 1450	1700	max. 1400	max. 1400 to 1450
Annealing treatment		Furnace cool from 1580°F.	—	Prolonged heating at 1250 to 1350°F.	1575 to 1625°F.	**	1 hr. or more at 1450°F. and quench

* Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.
† Quenched and drawn at 1100°F. †† Oil Quenched from 1650°F. and drawn.
** Small cold reduction, followed by anneal at 1400°F. and quench

Properties of the Principal Cr-Ni-Fe Alloys

	18-8	18-8	18-12	25-12	25-20	18-26
Chemical composition						
Chromium	17 to 19	Modifi-	17 to 19	22 to 28	24 to 26	17.5 to 19.5
Nickel	8 to 10	cation	11 to 12.5	12 to 16	19 to 21	25 to 26
Si and Mn (max.)	0.50	with	0.50	—	1.0 & 0.75	3.0 Si max.
Carbon	0.10	titanium	0.10	0.15±	0.15 max.	0.20 max.
Specific gravity						
Lb. per cu. in.	0.286	0.285	0.287	0.283	0.285	0.280
(Mild steel = 1.00)	1.01	1.01	1.02	1.0	1.01	0.99
Electrical resistance at 70°F.						
Microhms per cm.³	70 *	71	73	78	90±	102
(Mild steel = 1.00)	6.4	6.5	6.7	7.1	—	9.3
Melting range, °F.						
Top	2590	2590	—	2570	2600	—
Bottom	2550	2550	—	2530	2550	—
Structure	Austenitic	Austenitic	Austenitic	Austenitic	Austenitic	Austenitic
Magnetism						
Ferromagnetic	—	—	—	—	Trace	—
Permeability, As annealed	1.003	1.003	1.003	1.003	1.003	—
Permeability, Cold worked 10%	1.10	—	1.006	1.003	—	—
Specific heat						
C.g.s. units, 0 to 100°C.	0.12	0.12	0.12	0.12	—	—
(Mild steel = 1.00)	1.1	1.1	1.1	1.1	—	—
Thermal conductivity						
** C.g.s. units at 100°C.	0.0390	0.0385	0.0380	0.03 to 0.04	0.03 to 0.04	—
(Mild steel = 1.00)	0.33	0.32	0.32	0.25 to 0.35	0.25 to 0.35	—
C.g.s. units at 500°C.	0.0515	0.0528	0.0520	—	—	—
Thermal expansion per °F. x 1,000,000						
From 32 to 212°F.	9.6	9.3	9.9	8.3	8.8	8.8
(Mild steel = 1.00)	1.45	1.40	1.50	1.26	1.33	1.33
From 32 to 932°F.	10.2	10.3	10.8	9.6	9.4	9.3

Mechanical Properties at Room Temperature	18-8 Annealed	18-8 Cold Worked (Wire)	18-8 † Stabilized	18-12 Annealed	18-12 Cold Worked (Wire)	25-12 Annealed	25-12 Cold Worked (Wire)	25-20 Annealed	18-26 Annealed
Ultimate strength, 1000 psi.	80 to 95	105 to 300	80 to 95	80 to 90	105 to 275	90 to 110	110 to 270	80 to 110	90 to 110
Yield point, 1000 psi.	35 to 45	60 to 250	40 to 45	40	—	40 to 60	65 to 230	35 to 65	45 to 50
Elastic modulus, 10^6 psi.	29	—	—	—	—	—	—	—	30±
Elongation, % in 2 in.	65 to 55	—	60 to 50	60	—	50 to 35	—	60 to 45	35 to 30
in 10 in.	—	50 to 2	—	—	50 to 2	—	35 to 2	—	—
Reduction of area, %	65 to 55	65 to 30	65 to 55	65	65 to 30	60 to 45	55 to 20	—	45 to 35
Impact, ft-lb.; Charpy	80	—	77	—	—	—	—	40 to 80	—
Izod	75 to 110	—	—	—	—	—	—	—	50 to 90
Fatigue endurance limit, 1000 psi.	35	94	48	—	—	52	—	—	—
Corresponding ultimate strength	90	150	50	—	—	110	—	—	—
Hardness, Brinell	135 to 185	170 to 460	135 to 185	135 to 165	170 to 380	150 to 185	170 to 375	130 to 190	160 to 185
Rockwell	B-75 to 90	C-5 to 47	B-75 to 90	B-75 to 85	C-5 to 40	B-80 to 90	C-5 to 40	—	—
Erichsen value, mm.	11 to 14	—	—	—	—	—	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	17,000							—	7,000
1200	7,000							7,400	—
1350	3,000							3,300	—
1500	850							1,100	—
1600	—							—	1,900
Scaling temp., °F.	1650		1650	1650		2100		2000	1650
Initial forging temp., °F.	2200		—	As for 18-8		2200 to 2300		—	1950
Finishing temp., °F.	Not under 1600 to 1700		—	As for 18-8		Not under 1600 to 1700		—	—
Annealing treatment	Heat at 1900 to 2000°F. and quench		††	As for 18-8		Heat at 2000 to 2150°F. and quench		—	As for 18-8

* Electrical resistance of cold worked 18-8 ranges from 70 to 82 microhms per cm. cube

** Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.

† Small cold reduction, followed by anneal at 1400°F. and quench

†† Final heat treatment must consist of 2 to 4 hr. soak at 1550°F.

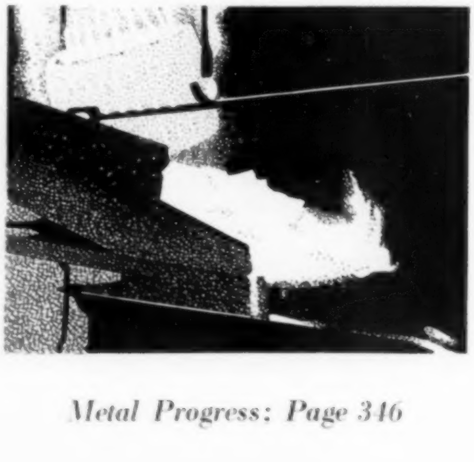
sections. Centrifugal casting, while making for more uniform wall section than available from usual sand casting methods, creates widely varied grain size and structural differences between the inner and outer surfaces. A new casting method known as "castruding" is being developed to provide the more desirable trilaminar structure of the sand casting with accurate and uniform wall sections.

These two items — modification of conventional analyses by small amounts of additional elements, and improvement in foundry practice — represent the metallurgical advances of note. Very significant changes have taken place in the mechanical design of furnace mechanisms, and the growing realization that alloy composition and even long alloy life are only part of a successful operation. Great strides in furnace engineering, burner design, additional control apparatus and pyrometry, have resulted in much better heating conditions under far closer control. It is now possible for the alloy engineer to really design for the job rather than to "add 100% and double" to protect against "hot spots and over-heating", or let the thickness of his foundrymen's skulls determine permissible wall section.

The effect of alloy mechanism in furnaces on alloy trays, conveyors, and other parts is now being given consideration. It is more important that rails be accurate and maintain their alignment, thereby greatly reducing pushing stress on costly trays, than that they be crude, heavy and outlast the furnace.

A good range of metallurgically dependable alloys is now available. Barring new discoveries of lower cost materials (which would take five years to prove) the future in alloys will be increasingly engineered alloys applied mechanically on the background of experience.

A new era of higher mechanization in heat treating furnaces is definitely here. Roller bearings operating at temperatures to 2000° F., spur gearing, internal gearing, and a wide variety of interrelated rotating and reciprocating parts are being introduced, a preponderance of such installations being of high nickel alloys because of the assurance of success derived from past experience.



80-20 Nickel-Chromium for Heating Elements

By W. A. Gatward
Chief Engineer
Hoskins Manufacturing Co., Detroit, Mich.

THERE HAS BEEN an enormous improvement in the durability of 80-20 nickel-chromium. The development of a test method was almost as much of a problem as was the improvement of the alloy, and it is nothing new that the test method must precede the improvement of the product. In most cases we already have a test method or at least we may simply have to modify the conditions to make them more severe as a product improves. We are used to being able to judge improvement readily and we may not appreciate the importance of the A.S.T.M. method for testing the oxidation resistance of nickel-chromium alloys. On the other hand, we should not forget that in the test the conditions are very clearly defined and limited, while the alloy in use must withstand many kinds of abuse, frequently far more damaging than simple oxidation.

The A.S.T.M life test was recently described in detail by F. E. Bash in METAL PROGRESS (February issue, page 143), so it is unnecessary to say more than that it follows the usual operating conditions as closely as possible, and the useful life of wire is "that elapsed test time required for a drop in wattage of 10%", even though this does not mean that a device would become inoperative.

In 1926 there was no practical, short time, controllable and reproducible life test. A very good wire of 80-20 nickel-chromium then had a useful life at 1950° F. of about 56 hr., as measured by the present A.S.T.M. life test. Today, a good wire of the same alloy would have a useful life of 1200 hr. Hence, we may say that the useful life of the resistor has been increased 21-fold.

It was fortunate that the 1926 quality of wire was better than the demands placed on it. In other words, the wire made good heating elements, but the full possibilities of the alloy were not demanded, nor known.

Most of the improvement has come in the last

three years. It has come on so fast that none can predict all that it may mean to the user of wire. We know that the present wire will last much longer at the same temperature (A.S.T.M. test) or that for the same length of time it will stand higher temperatures.

Cross-tests, using very poor and very good wires at various temperatures, indicate that 1938 wire can be operated at least 200° hotter than it could in 1926, and still give about the same life. As users begin to take advantage of this development, the degree of improvement will come to light.

Everyone prefers a test to which actual figures may be applied. Given the present method, one could easily become over-enthusiastic at the expense of good judgment. Other tests, although not so definite, have been applied, when necessary, to keep the design of the alloy in balance. No user of nickel-chromium would welcome an improvement in the alloy, as judged by the A.S.T.M. life test, if such "improvement" would interfere with other desirable qualities — such, for instance, as ductility.

The thing to do at present is to take advantage of this great improvement, remembering that other test methods are needed for judging definitely the quality in respect to life-consuming agencies other than pure oxidation.

Nickel, Monel and Inconel

By E. C. Badeau
International Nickel Co., New York City

SINCE NICKEL and its high nickel alloy companions, such as Inconel and Monel, are specialty metals, their use naturally increases with the growing demand for equipment having special characteristics, coming to light as manufacturers of all sorts intensify their search for more efficient, more economical, and longer lasting materials of construction.

Highly significant of these trends during the past year is growth in the airplane industry. Practically all the great land and sea planes completed or projected in the last twelve months have, or will have, exhaust collector rings and cabin heaters of Inconel. This alloy, containing approximately 79% nickel, 13% chromium, 7% iron, is highly resistant to heat and the corrosive conditions encountered. Furthermore, it is non-magnetic within the range of temperatures to which it is exposed and thus obtains additional value for use in proximity to the delicate instruments with which the modern plane is equipped. Developed originally for the dairy industry, its growing applications in aviation illustrate how the special properties of specialty groups of metals are adapted to a wide range of diversified fields.

Another newsworthy item is the use of approximately 60,000 lb. of rolled nickel for the lining of the cargo tanks of an ocean-going freighter. This vessel will carry caustic soda which must be free of iron, copper, or other harmful metallic contamination.

There have also been a number of developments in the metals themselves. Among these was the introduction of "Z Nickel", 98% nickel with 2% of other elements. This material can be heat treated to provide — with subsequent cold work — tensile strengths up to about 250,000 psi. Corrosion resistance and other characteristics of the metal are essentially the same as those of standard, rolled nickel.

Mill and laboratory research, together with sales developments have brought about wider applications for "K Monel", a heat-treatable alloy of Monel metal, containing a small amount of aluminum.

Both the above are rolled products. Activity also has been marked in extending the use of some of the newer forms of foundry products. Important among these are two varieties which differ from standard Monel in greater hardness and in the higher degree of their non-galling properties.

Inconel-clad steel has entered the field of bi-metals. As a companion to nickel-clad steel, it has been found useful where the relatively low cost of steel construction is desired with the corrosion resistance and other properties of Inconel. Perfection of a method for cladding rolls of steel, bronze, or aluminum with nickel alloys has recently led to the solution of many roll problems in the pulp, paper, textile and associated industries.

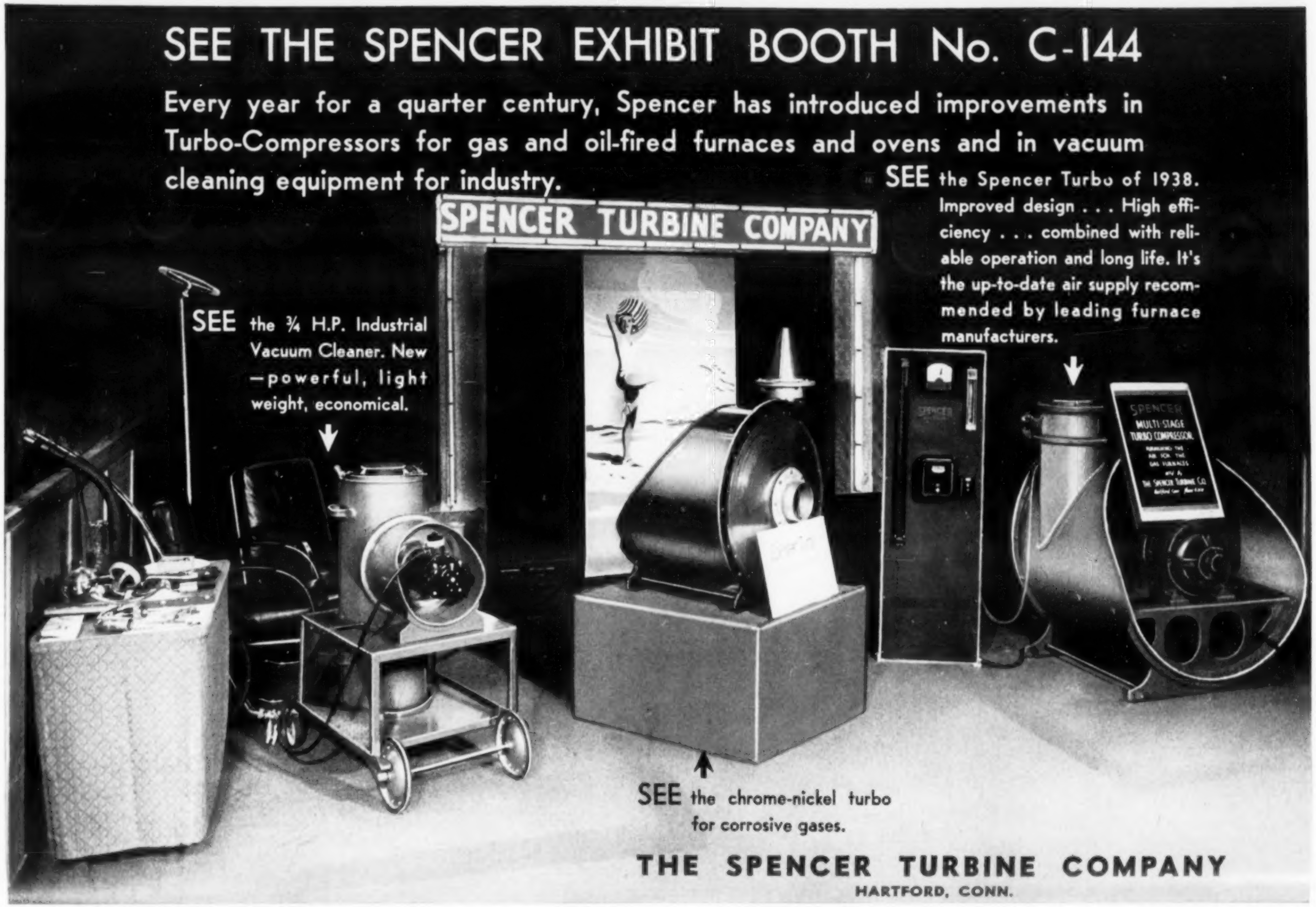
Appreciable quantities of nickel as anodes in electroplating baths were consumed during the year. The properties of nickel as a heavy corrosion resisting undercoat for chromium plating have become generally recognized. New improvements in bright plating practice have lowered cost and widened the field of heavy coatings. Experiments are being made on extra heavy coatings for corrosion resistance as distinct from appearance uses, and a growing ability has been noticed to electro-deposit nickel in broad ranges of ductility and hardness.

FURNACES

AND

REFRACTORIES

METAL PROGRESS OCTOBER, 1938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Furnaces

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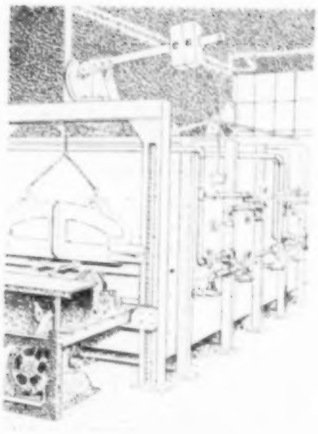

Openhearth Furnaces

By William C. Buell, Jr.
Engineer, Cleveland, Ohio

A CORRECT VIEW of the improvements in the openhearth should also include the handling equipment and the soaking pits. With this qualification it may be said that, while we have made great progress since the War, we have made more in the last six or seven years than in all prior years following the invention of the openhearth. An interesting case could be argued solely on the basis of *price* of standard products such as sheet steel. The many increases in the costs of various items required to make steel have been more than compensated by advances in practice.

One interesting general observation may be made concerning the general excellence of steel made from our common high-scrap charges. It is very significant, to me at least, that such plants as have both duplex and stationary shops invariably put all stationary capacity into service before the duplex is operated. Under peak conditions there will always be a demand for non-specification steel which can be filled by duplexed ingots.

At the present time one large producer is converting all tilting furnaces into stationary types, to produce satisfactory high-scrap steel for a new strip mill.

While the bessemer, duplex, Talbot and Monell processes still have a field of usefulness, particularly when maximum production is wanted, or when iron is low in cost and scrap high, they are definitely in the background where specification steel is to be produced. If I am right, scrap is a more valuable natural resource than iron ore.

Today the operation of a modern 125-ton furnace plant necessitates an investment of around $750,000 per unit. This includes the furnace, its auxiliaries, and its share of the buildings. With annual capital charges at 15%, cost is over $300 per day to carry such equipment, and, of course, continues during idle furnace time. The present trend is therefore toward the reduction of idle time by every practicable means.

Less than 15 years ago average roof life was 100 to 160 heats. Today if it is not at least 350 some shaking up would be in order. In bringing about this betterment I think Sam Naismith contributed much with his sloping back wall, which focused attention on roof life and offered a step toward its improvement. The refractory manufacturers followed with infinitely better roof brick, the masons developed a new technique in laying the roofs, and thus, through the joint efforts of many, came overall savings I estimate at about $1.50 per ton of ingots.

Furnace insulation has found its greater value in awakening operators to the cost of sloppy maintenance. It is my belief that the major part of the very real operating savings through the application of insulation comes through contingent items of betterment.

All concerned are giving much more thought to the development of end contours and some of us are working toward a fairly exact mathematical solution, as well as all general problems of fluid flow. Next to the roof, probably a greater betterment will be found through improvements in end design than is possible in any other component of the furnace system. Many older furnaces have been revamped in this respect.

Combustion of Common Gases

Adapted (by permission) from tables in 1938 issue of American Gas Catalog and Handbook

Material, Formula and Reaction		Molecular Weight	Specific Gravity (Air = 1.0)	Density at 60° F., 30 In. Barometer: Lb./Cu.Ft.	Density: Cu.Ft./Lb.	Specific Heat (H_2O = 1.0)	Heat of Combustion: B.t.u. per Cu.Ft. Gross	B.t.u. per Cu.Ft. Net	B.t.u. per Lb. Gross	B.t.u. per Lb. Net	Cu.Ft. per Cu.Ft. Combustible: Required for Combustion: Air	Required: O_2	Products of Combustion in Air: CO_2	Products: H_2O	Products: N_2
Carbon, C (to CO)	$C+\frac{1}{2}O_2=CO$	12.010	.....	......	.....	....	......	......	4,001	4,001	2.382*	0.5*	1.0* CO	...	1.882*
Carbon, C (to CO_2)	$C+O_2=CO_2$	12.010	.....	......	.....	....	......	......	14,136	14,136	4.764*	1.0*	1.0*	...	3.764*
Carbon monoxide, CO	$CO+\frac{1}{2}O_2=CO_2$	28.010	0.9667	0.07402	13.509	0.243	321.7	321.7	4,346	4,346	2.382	0.5	1.0	...	1.882
Carbon dioxide, CO_2		44.010	1.5289	0.11707	8.542	0.203	......	......	.....	.....	....	...	...	...	......
Hydrogen, H_2	$H_2+\frac{1}{2}O_2=H_2O$	2.0162	0.06951	0.005323	187.881	3.409	325.0	274.6	61,061	51,592	2.382	0.5	...	1.0	1.882
Paraffin Series, C_nH_{2n+2}															
Methane, CH_4	$CH_4+2O_2=CO_2+2H_2O$	16.042	0.5548	0.04248	23.542	0.593	1,015.0	914.0	23,896	21,517	9.528	2.0	1.0	2.0	7.528
Ethane, C_2H_6	$C_2H_6+3\frac{1}{2}O_2=2CO_2+3H_2O$	30.069	1.0468	0.08016	12.475	0.397	1,790	1,637	22,330	20,422	16.674	3.5	2.0	3.0	13.174
Propane, C_3H_8	$C_3H_8+5O_2=3CO_2+4H_2O$	44.095	1.550	0.11866	8.427	0.365	2,572	2,366	21,675	19,939	23.820	5.0	3.0	4.0	18.820
n-Butane, C_4H_{10}	$C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	58.121	2.078	0.1591	6.284	0.351	3,393	3,132	21,321	19,681	30.966	6.5	4.0	5.0	24.466
Iso-Butane, C_4H_{10}	$C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	58.121	2.066	0.15815	6.323	0.351	3,364	3,105	21,271	19,633	30.966	6.5	4.0	5.0	24.466
n-Pentane, C_5H_{12}	$C_5H_{12}+8O_2=5CO_2+6H_2O$	72.147	2.49*	0.1907*	5.245*	....	4,023*	3,720*	21,101	19,511	38.112*	8.0*	5.0	6.0	30.112
n-Hexane, C_6H_{14}	$C_6H_{14}+9\frac{1}{2}O_2=6CO_2+7H_2O$	86.173	2.97*	0.2277*	4.392*	....	4,771*	4,418*	20,954	19,404	45.258*	9.5*	6.0	7.0	35.758
Olefin Series, C_nH_{2n}															
Ethylene, C_2H_4	$C_2H_4+3O_2=2CO_2+2H_2O$	28.052	0.9747	0.07464	13.398	0.363	1,615	1,514	21,638	20,285	14.292	3.0	2.0	2.0	11.292
Propylene, C_3H_6	$C_3H_6+4\frac{1}{2}O_2=3CO_2+3H_2O$	42.079	1.481	0.11340	8.819	....	2,380	2,226	20,990	19,630	21.438	4.5	3.0	3.0	16.938
Butylene, C_4H_8	$C_4H_8+6O_2=4CO_2+4H_2O$	56.105	1.935	0.1482	6.750	....	3,079	2,877	20,780	19,420	28.584	6.0	4.0	4.0	22.584
Aromatic Series,															
Benzene, C_6H_6	$C_6H_6+7\frac{1}{2}O_2=6CO_2+3H_2O$	78.109	2.712*	0.2076*	4.816*	....	3,758*	3,607*	18,100(a)	17,370(a)	35.730*	7.5*	6.0	3.0	28.230
Toluene, C_7H_8	$C_7H_8+9O_2=7CO_2+4H_2O$	92.135	3.177*	0.2433*	4.110*	....	4,452*	4,250*	18,300(a)	17,470(a)	42.876*	9.0*	7.0	4.0	33.876
Xylene, C_8H_{10}	$C_8H_{10}+10\frac{1}{2}O_2=8CO_2+5H_2O$	106.161	3.661*	0.2803*	3.567*	....	5,189*	4,937*	18,510(a)	17,610(a)	50.022*	10.5*	8.0	5.0	39.522
Acetylene, C_2H_2	$C_2H_2+2\frac{1}{2}O_2=2CO_2+H_2O$	26.036	0.907	0.06946	14.396	0.383	1,491	1,440	21,460	20,730	11.910	2.5	2.0	1.0	9.410
Naphthalene, $C_{10}H_8$	$C_{10}H_8+12O_2=10CO_2+4H_2O$	128.165	.....	......	.....	....	......	......	17,314(b)	16,718(b)	57.168*	12.0*	10.0	4.0	45.168
Ammonia, NH_3	$NH_3+\frac{3}{4}O_2=\frac{1}{2}N_2+1\frac{1}{2}H_2O$	17.032	0.5966	0.04568	21.890	0.520	442	365	9,678	8,000	3.573	0.75	...	1.5	3.323
Nitrous oxide, N_2O		44.016	1.530	0.11712	8.538	0.221	......	......	.....	.....	....	...	...	...	......
Nitric oxide, NO		30.008	1.0365	0.07936	12.600	0.232	......	......	.....	.....	....	...	...	...	......
Hydrogen sulphide, H_2S	$H_2S+1\frac{1}{2}O_2=SO_2+H_2O$	34.076	1.1902	0.09114	10.973	0.245	637	586	6,992	6,432	7.146	1.5	1.0 SO_2	1.0	5.646
Sulphur dioxide, SO_2		64.060	2.2636	0.17333	5.769	0.154	......	......	.....	.....	....	...	...	...	......
Water vapor, H_2O		18.016	0.6220*	0.04763*	20.995*	0.48	......	......	.....	.....	....	...	...	...	......
Oxygen, O_2		32.0000	1.1051	0.08462	11.818	0.217	......	......	.....	.....	....	...	...	...	......
Nitrogen, N_2		28.016	0.9671	0.07405	13.504	0.244	......	......	.....	.....	....	...	...	...	......
Nitrogen ("Atmospheric") (c)		28.161	0.9721	0.07443	13.435	0.242	......	......	.....	.....	....	...	...	...	......
Air (d)		.....	1.0000	0.07657	13.060	0.2375	......	......	.....	.....	....	...	...	...	......

Typical Commercial Gases

Kind of Gas	Constituents of Gas—Per Cent by Volume: CO_2	Ill.	O_2	CO	CH_4	C_2H_6	H_2	N_2	Specific Gravity (Air = 1.0)	Lb./Cu.Ft.	Cu.Ft./Lb.	Specific Heat	B.t.u. per Cu.Ft. Gross	B.t.u. per Cu.Ft. Net	B.t.u. per Lb. Gross	B.t.u. per Lb. Net	Air	O_2	CO_2	H_2O	N_2
Natural gas																					
Mid-Continent	0.8	...	...	...	96.0	...	...	3.2	0.575	0.0440	22.71	....	974	877	22,122	19,919	9.15	...	0.968	1.92	7.26
Ohio	...	...	...	...	80.5	18.2	...	1.3	0.650	0.0498	20.09	....	1,143	1,034	22,966	20,775	10.70	...	1.169	2.16	8.47
Pennsylvania	...	...	...	...	67.6	31.3	...	1.1	0.714	0.0547	18.29	....	1,247	1,131	22,809	20.687	11.66	...	1.302	2.29	9.22
California	0.8	...	...	...	75.1	23.0	...	1.1	0.680	0.0521	19.21	....	1,174	1,063	22,548	20,416	10.99	...	1.219	2.19	8.69
Coal gas																					
Horizontal retort	2.1	3.8	0.4	8.7	28.2	2.8	50.5	3.5	0.431	0.0330	30.30	....	613	550	18,575	16,666	5.32	...	0.566	1.240	4.24
Horizontal retort	2.8	4.5	0.6	7.4	34.3	...	41.6	8.8	0.493	0.0377	26.49	....	609	548	16,133	14,517	5.35	...	0.591	1.206	4.32
Vertical retort	3.0	3.1	0.6	7.0	32.8	...	50.4	3.1	0.397	0.0304	32.90	....	569	507	18,718	16,679	4.91	...	0.490	1.222	3.91
By-product coke oven gas	2.1	3.2	0.4	6.4	30.3	...	53.9	3.7	0.378	0.0289	34.55	....	563	502	19,452	17,344	4.85	...	0.468	1.213	3.87
Water gas																					
Carburetted	3.3	10.7	0.7	33.4	10.0	...	38.1	3.8	0.651	0.0498	20.06	....	562	521	11,274	10,452	4.73	...	0.789	0.822	3.78
Carburetted	4.7	10.8	1.1	25.9	14.5	...	33.2	9.8	0.685	0.0525	19.07	....	569	526	10,848	9,964	4.86	...	0.775	0.865	3.94
Uncarburetted	5.0	...	0.5	44.0	2.0	...	44.0	4.5	0.593	0.0454	22.02	....	305	281	6,717	6,189	2.26	...	0.510	0.480	1.83
Pacific Coast oil gas	6.3	4.6	0.4	12.6	26.1	...	45.6	4.4	0.509	0.0390	25.66	....	555	501	14,240	12,855	4.79	...	0.594	1.083	3.83
Producer gas																					
Anthracite coal	6.6	0.3	...	25.1	0.3	...	18.7	49.0	0.837	0.0641	15.60	....	149	139	2,325	2,169	1.115	...	0.326	0.199	1.371
Bituminous coal	2.5	0.4	0.3	27.0	2.5	...	12.0	55.3	0.866	0.0663	15.08	....	158	149	2,383	2,247	1.210	...	0.328	0.178	1.509
Blast furnace gas	14.5	...	...	22.8	..	...	5.1	57.6	1.006	0.0770	12.98	....	90	87	1,168	1,129	0.665	...	0.373	0.051	1.101

Notes: *Figure calculated on assumption that substance could exist as gas at 60° F. and 30 in. of mercury.

(a) Liquid
(b) Solid
(c) Contains 0.94% argon by volume, about 0.03% CO_2 and trace of hydrogen.

(d) Purified, dry air contains 20.99% oxygen and 79.01% nitrogen and other inert gases by volume (or 23.20% oxygen and 76.80% nitrogen by weight).

We have given too much study to the value of checker-work as such, rather than to the causes of checker inefficiency. The chief cause of poor checker operation is gas borne solids that foul or glaze the brickwork. The existing problem therefore is not one of brick at all, but chiefly of gas cleaning. We are making progress in developing gas cleaning apparatus to be placed between slag pockets and regenerators that should be a great aid.

Instrumental control of certain factors of operation has been found advantageous when properly engineered, operated and maintained. While I have no desire to belittle the value of control, I do believe that in many instances much of the savings ascribed are due to a centering of attention on certain items of operation previously overlooked which, when properly attended to, produce much of the betterment attributed to the control apparatus. Among the control apparatus I would place the following in the order of their value: First, draft control, then reversal by temperature.

Foundry Furnaces

By Donald J. Reese
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AN exceedingly wide variety of analyses have made almost indistinguishable the boundary between steel and malleable and malleable and gray iron. Similar variations, although of less extent, have taken place in other phases of foundry practice, including furnaces used for melting the iron.

For malleable iron the reverberatory furnace, developed in this country, was the standard melting furnace for over 100 years and though some malleable was melted in a cupola, "cupola malleable" was lower in physical properties. Today a considerable portion is melted by a duplex process involving a cupola and either an electric furnace, a rotary furnace or a reverberatory furnace. Qualities of this malleable are in the high brackets.

In the steel foundry an interesting possibility is the speeding up of the openhearth process with appreciable savings in the use of cupola melted "hot metal" instead of using cold pig iron, a process which is already in use in one of the steel mills.

Cast iron, long the Cinderella of ferrous materials, is also in the process of greatly improving its qualities. Though the greatest tonnage has always been melted in cupolas, some has always been melted in reverberatory furnaces, and for some years electric furnaces, rotary furnaces and crucible furnaces have also been found in foundries. One large producer has the following furnaces in the melting circuit in the sequence given: Cupolas, mixers, electric furnaces, and reverberatory.

Most steel melting is done in electric furnaces. Some openhearths and converters are still in service. An improvement in electric furnaces has been the removable roof to permit mechanical charging instead of hand charging. In the newer electric furnaces more attention is given to water jacketing, sealing the furnace from air currents, and minimizing the contact of metal and air at the time of tapping.

A relationship between the character of the furnace slag and the quality of metal produced is now recognized. Melting and pouring temperatures are held within definite tolerances with optical pyrometer control.

The foundry industry is old and existed largely by rule of thumb methods until within recent years. The art of foundry production is finally giving way to more scientific methods, and progress in the next few years will keep pace with that made in the recent past.

Heat Production
Burners and Radiant Tubes

By E. G. de Coriolis
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METHODS of heat production in industrial heat treating plants have witnessed some improvement within the past year. High pressure velocity burners, in which the pressure of the gas injects its full complement of combustion air, are now available with a highly refractory nose. This nose fits next to a cast refractory block made in several sections rather than the conventional rammed lining. This change in construction has increased the burner capacity and its range of turndown, as it eliminates back firing entirely.

Variable flame burners adaptable to multipurpose furnaces have a manual adjustment which varies the amount of air premixed with the fuel gas at the burner port. This type of burner may be changed at will from a short sharp flame to a long luminous flame while holding within reasonable limits the same proportion of air to gas for combustion.

A new type of gas-oil burner is now available for forging furnaces in plants located in the natural gas district. This burner at full capacity consumes 70% of its energy in the form of natural gas and the remaining 30% in the form of fuel oil. The intense heat of the gas flame quickly gasifies the oil resulting in a white luminous flame which heats rapidly and makes an ideal burner for forge furnace operation.

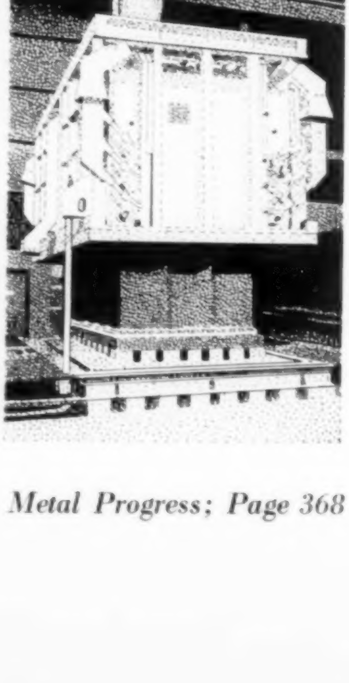
The problem of heating pickling tanks without the use of steam, which reduces the concentration of the pickle liquor, is now successfully solved by using a submersion burner. Gas and air under pressure, which varies with the hydrostatic head of the tank, are forced down into one or more burner heads. The latter have a distributing cross pipe at the bottom to disseminate the products of combustion in small bubbles. Excellent agitation of the pickle solution and 100% heat absorption are effected.

The application of radiant tubes to industrial furnace heating continues to broaden. The increasing demand for atmosphere furnaces of many and varied types is facilitated by applying radiant gas fired heating elements, the only limitation to date being the very high temperature furnaces such as copper brazing where the life of available alloys at such high temperature would not warrant the use of these tubes from an economic standpoint.

Heat treating furnaces using radiant tubes are now to be found in the automotive, steel and non-ferrous industries performing almost every type of operation. In furnaces for short cycle malleableizing they have eliminated heavy containers and, coupled with the adaptation of controlled atmospheres, have produced on a large scale fully malleableized iron on cycles of one-third and even less time than heretofore possible. Another advantage possessed by radiant tubes is causing its introduction into some plants where ventilating conditions are such that the waste products of combustion cannot be allowed to escape within the room, but must be piped directly outdoors.

In a field allied to the metal industry in the sense that it utilizes large quantities of metal, namely, the vitreous enamel field, the number of radiant tube installations is constantly on the increase. The highest grade of enamel ware has been produced from such furnaces and at costs which are substantially below the troublesome, old fashioned ceramic muffle.

The type of combustion developed for successful application to radiant tubes has also made this method adaptable to immersion heating elements for solution heating. One of the more recent of such applications is the heating of rust proofing solutions in auto body plants.



Combustion of Gas and Oil

By E. O. Mattocks
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GREAT ADVANCE in the knowledge of what happens when gas and oil are burned has occurred during the past few years. Combustion is no longer considered satisfactory with the mere liberation of heat. Today the combustion reaction must be accomplished at the maximum rate of heat liberation in the minimum of space, and with the evolution of a quantity of uniform flue products whose composition is under control, within limits. This requires two things, first, a working knowledge of the combustion reaction, and second, a uniform fuel.

The most modern theory of the combustion of a gas, which has replaced almost completely all previous ones, is the so-called hydroxylation theory. In the main this theory states that if a gas is ignited it will burn by steps of progressive oxidation until it is completely consumed, assuming no interference and an ample supply of oxygen. The intermediate products may be alcohols, aldehydes, carbon monoxide and hydrogen. These products are eventually burned to carbon dioxide and water vapor if the process is allowed to go to completion. This process will apply, probably, to all hydrocarbon fuels encountered today, both gaseous and liquid, assuming that the liquid fuels are first entirely vaporized.

Combustion of oil is an extremely complicated process. The general theory requires that a liquid fuel must first be vaporized before it can be burned. The greater the degree of atomization (the finer the formation

of droplets) the more rapid the vaporization and the less space required for combustion. Likewise the greater the atomization, the greater the possibility of premixing air prior to the combustion action. Since the degree of premixing affects the amount of space required for combustion, the greater the degree of premixing of air and atomized fuel, the less space required for complete combustion. After oil is vaporized it probably burns much like a gas.

To some degree conditions of heat liberation rule the resulting combustion process. Temperature, pressure, combustion chamber design and material, degree and thoroughness of premixing air and fuel, are all factors which have to be taken into consideration. If a mixture of fuel gas and air is thoroughly premixed, over 9,000,000 B.t.u. per hr. can be completely burned per cubic foot of combustion space of a relatively fast burning gas! As the rate of flame propagation decreases, the maximum amount of heat liberated decreases. Likewise as the combustion process is made rich (if CO, H_2 and possibly CH_4 are desired) still less amount of gas can be burned to a state of equilibrium in a given combustion space. In a similar manner the degree and amount of premixing affect the amount of heat that can be liberated per unit of space.

Knowing some of the limitations of the combustion process, combustion chambers can now be designed to use a minimum amount of space. While the theory is advanced by some writers that the flue products are controlled to a great extent by the water-gas reaction ($CO + H_2O \rightleftarrows CO_2 + H_2$) there are also a number of other factors which appear to have influence such as *(a)* catalytic effect of the material in the combustion chamber, *(b)* dissociation of some of the flue products, *(c)* the action of pressure. Some of these factors are recognized and attempts are being made to investigate them, but no complete data are available at present.

However we can state in a general manner the type of fuel best suited for a given operation. Some fuels such as oil produce more radiant energy per unit of heat input than others and are therefore better suited for higher temperature operations, while other fuels of a lower carbon content per heat unit are better suited for lower temperature convection heating. While it is possible to estimate the composition of the flue products, knowing the composition of the fuel and the air-fuel ratio, our reliable data are usually empirical.

By learning more about the combustion process of fuels greater ease of controlling furnace operations will result. The possibility of controlling the composition of certain elements in metals by furnace atmospheres has yet to be fully evaluated, although it is now a matter of paramount interest to the metallurgical industry. Although great strides have been made in recent years through greater knowledge of the combustion process, still greater achievements are yet to come.

Improved Refractories

By John D. Sullivan
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THE NEED for improved refractories became acute during and after the World War when changes in metallurgical practices and the requirement of greater tonnage output from furnaces created a demand which the commercial refractories of that time did not meet. The manufacturers attempted to meet these requirements and many new products appeared on the market. It soon became apparent that no "cure-all" was to be found in a short time, and that chemical composition alone was not the sole requirement for excellent refractories.

Progress was rapidly made in general manufacturing technique and the properties of practically all refractories were greatly improved. These changes were quite gradual, but looking back over a period of 15 years we realize the vast improvements which have been made. Today in all refractories the need is recognized for careful selection of particle size to govern density and porosity. The advent of de-airing and vacuum pressing was another step in the same direction. It should be pointed out that no single innovation effected all the improvements that have been made. Each contributed its part and when used with others still greater benefits were derived.

While improvements and innovations were being made along physical lines, chemical studies were not being neglected. Investigations into the thermal mineralogy of refractory materials and bodies led to the utilization of materials that were considered worthless a quarter of a century ago. In this respect reference need only be made to the use of flint fireclays to produce the so-called "super duty" fireclay brick. This, in fact, is an entirely new

Properties of Refractory Materials, Except Fireclay

Compiled by Stuart M. Phelps, and Copyrighted 1935 by American Refractories Institute, Technical Dept., Mellon Institute.

Material (1)	Composition of the Pure Material		Melting Point	True Specific Gravity	Hardness (Moh's Scale)	Mean Specific Heat (17)	Thermal Expansion (Note 22)	Thermal Conductivity (2)		
	Formula	Composition %						At 1000° F.	At 1600° F.	At 2400° F.
Andalusite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810° C. 3290° F.	3.20	7.5	0.168 (18)	6.2*			
Chromite	$FeO.Cr_2O_3$ (3)	Cr_2O_3 68 FeO 32	2180° C. 3956° F.	4.5	5.5	0.22*	8.0*	10.0*	10.9*	12.1*
Corundum	Al_2O_3	Al_2O_3 100	2050° C. 3722° F.	4.0 (24)	9	0.304*	8.5	23.0*	26.5*	30.0*
Cyanite (Kyanite)	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810° C. 3290° F.	3.6 ±	4 to 7		4.9* (4)			
Diasporite (Diaspore) (5)	$Al_2O_3.H_2O$	Al_2O_3 85.1 H_2O 14.9	2050° C. 3722° F.	3.4 to 3.5	6.5 to 7	(Note 6)	6.5*			
Dolomite	$CaCO_3.MgCO_3$	CaO 30.4 MgO 21.9 CO_2 47.7	(Note 23)	2.81 to 2.95	3.5 to 4.0	0.222 (19)	14.0			
Dumortierite	$8Al_2O_3.6SiO_2.B_2O_3.H_2O$	SiO_2 64.6 Al_2O_3 28.5 B_2O_3 5.5 H_2O 1.4	1810° C. 3290° F.	3.30	7		5.2*			
Forsterite	$2MgO.SiO_2$	MgO 57.3 SiO_2 42.7	1910° C. 3470° F.	3.22	6 to 7	0.22 (19)	10.5*	11.1*	10.6*	10.3*
Graphite	C	C 100	>3000° C. >5432° F.	2.25	1 to 2	0.29	2.2			
Magnesia spinel	$MgO.Al_2O_3$	MgO 28.2 Al_2O_3 71.8	2135° C. 3875° F.	3.6	8	0.257	8.5	12.2*	13.3*	14.5*
Mullite	$3Al_2O_3.2SiO_2$	Al_2O_3 71.8 SiO_2 28.2	1810° C. 3290° F.	3.03		0.175 (20)	5.3 (7)			
Periclase (Magnesia) (8)	MgO	MgO 100	2800° C. 5072° F.	3.64 to 3.67	5.5 to 6.0	0.285	13.5*	19.5*	15.5*	13.0*
Quartz (9) (Quartzite)	SiO_2	Silica 100	1400° C. (10) 2552° F.	2.653	7	0.263*	32.6* (11) 4.6 (12)	8.8*	10.7*	13.3*
Silicon carbide	SiC	Si 70 C 30	2250° C. (13) 4082° F.	3.17 to 3.21	9 to 10	0.19 (14)	5.2 (15)	142*	110*	80*
Sillimanite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810° C. 3290° F.	3.24	6.5 to 7.5	0.175				
Zircon (Zirconium silicate)	$ZrO_2.SiO_2$	ZrO_2 67.1 SiO_2 32.9	2550° C. 4622° F.	4.7	7.5	0.132 (21)	4.5			
Zirconia (Zirconium oxide)	ZrO_2	Zr 73.9 O_2 26.1	2700° C. 4892° F.	5.5 to 6.0	6.5	0.16	6.6 (16)	12.0*	13.0*	14.0*

*1. These properties refer to pure materials and not to commercial refractories which may differ because of impurities, bonding materials, and process of manufacture. The specific heat, thermal expansion and thermal conductivity data, however, may be used for engineering purposes and especially those marked with asterisk (*) which were obtained from commercial products.

2. Thermal conductivity in B.t.u. per in., per hr., per sq.ft., per °F., averaged from the more reliable data on refractories.

3. General chemical formula for chromite is $RO \cdot R_2O_3$. The RO oxide is usually FeO and may be replaced in part by MgO, while the R_2O_3 is mostly Cr_2O_3, but may be replaced in part by Al_2O_3 and Fe_2O_3.

4. Indian.

5. Commercial diaspore is composed of diasporite grains bonded with clay.

6. Probably close to 0.26.

7. Synthetic, pure.

8. Magnesite is amorphous, or crystalline like periclase, depending upon the heat treatment it has received.

9. Ganister is the commercial form for use in refractories, about 98% silica.

10. Crystobalite is the stable form of silica above 1470° C., and has the melting point of 1713° C. (3115° F.).

11. Value is for silica brick, mean expansion in range 20 to 300° C.

12. Value is for quartz, mean expansion in range 300 to 1135° C.

13. Dissociation temperature; oxidation may begin at 900° C. (1652° F.).

14. Varies with temperature.

15. This figure, and those for thermal conductivity, are for recrystallized material.

16. Pure material sintered.

17. For the range 20 to 1000° C. (68 to 1832° F.) unless noted.

18. For the range 0 to 100° C.

19. For the range 20 to 100° C.

20. For the range 20 to 800° C.

21. For the range 21 to 51° C.

22. Values for the mean reversible thermal expansion per ° C. times 10^6, for the range 20 to 1000° C. unless noted.

23. Dissociates at very high temperatures.

24. Alpha modification.

classification of fireclay brick, and price quotations were first published in 1935. Another example of a new product developed by research and application of scientific principles is unburned magnesite and chrome brick.

With the production of better refractories in shapes, more attention was paid to mortars for laying them, when it was realized that poor joints frequently resulted in failure of a structure. Better mortars in no small way have contributed to better refractory service.

Since many of the regular or common products of today would have been considered special refractories at the time of the War, it is rather difficult to draw a clear line of demarcation between "standard" and "special" refractories. As noted above the demand for special refractories resulted in improvements all along the line until we now take most of the new products for granted and no longer consider them special. However the term "special refractories" may be reserved for the less frequently used ones in the higher price brackets.

Silicon carbide and corundum are the raw materials usually used for special refractory brick, tile, and other shapes. Electrically fused and cast blocks of mullite are also widely used in the glass industry. Rarer oxides, especially of beryllium, zirconium and titanium, are now being used for small shapes and articles such as crucibles, insulators, parts of vacuum tubes and the like.

The commercial value of these special refractories is not small. According to Census figures it amounted to $2,900,000 in the depression year of 1932, and $7,500,000 in 1936.

At present the greatest demand for special refractories is in fields where some specific property, for example high refractoriness, high thermal conductivity or unusual load-bearing properties at high temperatures, is required. A smaller demand is for installations where special purity is required in crucibles and the like to prevent contamination of the metal, alloy or glass being made. Castables made of refractory grog and hydraulic cement find use in intricate shapes and sizes. Refractory plastics and ramming mixes are also important.

As for the future, there will be continued demands for better refractories and the manufacturers will attempt to meet them. This will be done in part by improvement in ordinary refractories, in part by extended use of current special refractories, and in part by new products which will be developed.

Insulation

By J. B. Austin
Kearny, N. J.

THE ACTIVE INTEREST in the insulation of metallurgical furnaces — so evident in the steel industry in the last few years — shows definite signs of diminishing. This does not mean that insulation is being discredited, although a few operators have given it up, nor does it imply that no new insulated furnaces are being installed, but rather that the first enthusiasm is now over and with increasing experience a more tempered judgment is being used.

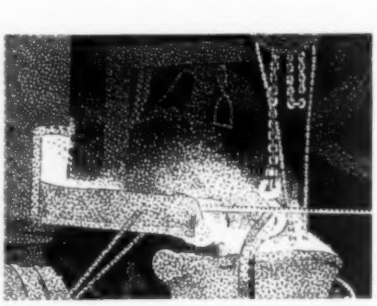
The chief mistakes made at the first were the use of thicker insulation than was necessary or even desirable, and the failure to realize that an insulated furnace requires much finer control. More than one insulated openhearth roof has been severely damaged by a temporary over-heating which would not have harmed an uninsulated furnace. In other cases where fireclay was used, it was not at first recognized that the strength of the structure depended on keeping part of the refractory cool enough to carry the load; failure occurred when the fireclay was raised to a much higher mean temperature by bottling the heat up by insulation.

In the matter of thickness, it was a natural error to assume that if insulation was effective at all, the more the better. The fallacy of this conclusion is now more widely recognized. Not only does very thick insulation make close control more necessary, but it may even be uneconomical in itself. Thus, in many cases there is a rapidly diminishing return in heat saving as thickness increases — that is, the fourth inch does not save as much heat as the first, yet the cost per unit thickness remains the same. There is therefore an optimum thickness at which the cost per unit of heat saved is a minimum. Consumers are not always aware of this fact.

Interest in insulation outside the steel industry seems to be gaining steadily. For example, the copper industry is beginning to become "insulation conscious" and will undoubtedly be more so in the near future. Activity on the part of the producers of insulation continues unabated; in fact, competition grows daily more keen as numerous new brands are introduced. These are in most cases merely new brands rather than basically new products, and differ but little in composition and properties within a given class of material.

Perhaps the most interesting development

of recent years is the class of materials known as "insulating refractories" as contrasted with refractories proper and the refractory insulators. Until a few years ago, the only materials available for furnace construction were the refractories to be used in contact with the furnace atmosphere, and the insulating materials to be used behind the refractories. Now, however, there are numerous light weight brick which are fairly good insulators yet are refractory enough to be exposed directly to the furnace heat. They are essentially a refractory brick made by adding volatile or combustible matter to the mix. This material is removed during firing leaving a strong yet porous brick which is a fair insulator. A wall made of such brick stores but little heat so that there is only a relatively small loss of heat in the walls during each heating and cooling cycle — a matter of especial advantage in furnaces operated intermittently.



Of the newer insulating materials, the most interesting is the expanded mica now available in the form of granules, block, brick, and coatings. Because of the porous nature of these granules they make effective insulators and their use is growing rapidly. Another useful and fairly new class of insulators is being made by incorporating wool (made from slag, minerals, or glass) in a coating or block. This is a promising development and it is likely that a great deal more will be heard of it in the near future.

Foundry Refractories

By J. A. Bowers
American Cast Iron Pipe Co., Birmingham, Ala.

MELTING DEPARTMENTS in the modern cast iron foundries are constantly being called upon for hotter iron and usually these higher temperatures must be maintained over long periods of time. One of the newer developments, more important every day, is the forehearth in which molten metal can be accumulated and held, usually in quite large quantities, for the entire length of the heat. This means that exceptionally good ladle refractories must be used for this unit and since the forehearth requires a continuous stream of metal, the iron trough must be carefully constructed. Even the present day foundry ladle must transport iron throughout an entire heat, for in large foundries the casting operation usually continues uninterrupted for the entire day. From this can be readily seen the increasing importance of refractories in the modern foundry.

One of the most important things to be considered is the selection of the proper refractory. This will depend on the type of melting unit, which usually is the cupola. The two prime requisites for firebrick to be used in the melting zone, the point of maximum consumption, is that they be highly refractory and very close grained or dense. Natural silica stone has proven successful in some foundries. The modern cupola is often equipped to deliver a continuous stream of iron and slag from the tap hole. The slag is skimmed from the iron at a very short distance from the cupola and removed by a side trough. Since slag is the worst enemy of most refractories, this trough is usually made rather short and lined with a monolithic refractory of good quality.

The forehearth requires as much care in lining as in the selection of refractory, particularly where desulphurizing is done. Refractories that offer excellent resistance to chemical and erosive action and are comparatively high in their resistance to spalling should be selected. The brick should be placed as closely together as possible, using a soupy fireclay mortar. If the forehearth is prepared with care it may last several hundred heats with only minor periodic repairs. If the iron is to be desulphurized, even more carefully made joints are necessary along the zone of contact with the desulphurizing medium. Forehearths of this type are usually repaired daily, from the lowest point of slag contact to the top, with a monolithic lining of good quality fireclay. Rammed linings of plastic refractory are now available and are proving very satisfactory.

Refractory manufacturers have increased the number and diversity of shapes. Cupola blocks have been on the market for a number of years, but the foundryman may now buy tap hole bricks with one, two, and three holes, so that the blast pressure may be varied over extremely wide ranges and yet allow a continuous stream of iron to flow from the cupola. Skimming tiles for separating slag from the

iron are available in almost any size and thickness. Semi-cylindrical tile can be had to transform an ordinary ladle into the teapot type. These shapes, along with tile for ladle bottoms, and sidewall segments with lap joints, have cut the mason labor costs unbelievably.

Manufacturers have also made such improvements in composition and technique for making extremely intricate shapes that it is reasonable to suppose that refractories will become more and more important in the foundry. If foundryman and ceramist will cooperate, perhaps refractories might in some instances replace sand. Semi-permanent molds of refractory materials for small repeat castings might often prove satisfactory.

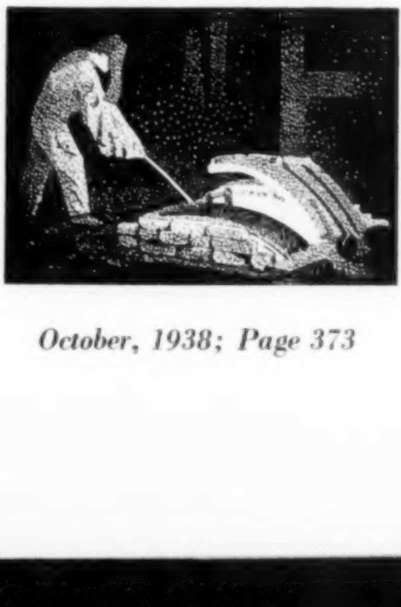
Soaking Pits and Slab Heaters

By P. F. Kinyoun
Combustion Engineer, Bethlehem Steel Co.
Lackawanna, N. Y.

WELL DESIGNED and well operated soaking pits and slab reheating furnaces contribute greatly to the precision rolling of steel into strip, sheets and plate. Three types of soaking pits are used in the steel industry today, *(a)* the reversing, regenerative pit; *(b)* the non-reversing, recuperative; *(c)* the non-reversing, non-recuperative. The major portion of slab heating is carried out in continuous triple-fired furnaces.

The most commonly used soaking pit is the conventional reversing and regenerative type. It is readily fired with any of the gas fuels; in some cases fuel oil has also been used. Because a high degree of air preheat is obtainable, this type lends itself very well to fuels of low thermal value, such as mixed blast furnace and coke oven gas, and if well insulated, automatically reversed and under good combustion control, is heating hot ingots with a consumption of 750,000 B.t.u. per gross ton.

The one-way fired pit has been used to some extent, wherein the fuel enters at one end and the products of combustion leave at the same end, but at a lower level. This type has advantages as to space requirements and absence of reversing mechanism, but is somewhat limited in the degree of air preheat obtainable from the recuperators used instead of regenerators. The most recent installations are equipped with recuperators for both the air and fuel gas, and are reported to be operating satisfactorily on fuels of low thermal value.



The latest designs are the circular and the square pits. They are either fired tangentially around the sides or at the center and through the bottom. The design that employs tangential firing has no regenerators or recuperators, with the result that it must now be heated by the richer fuels. The square pit fired in the center and through the bottom is equipped with recuperators for preheating the combustion air (and in some cases both the air and fuel gas). A leading Canadian steel plant reports good results with the latter when using a low thermal value fuel. Square pits have a large capacity in respect to number of ingots that can be charged and heated, and are well adapted to the application of combustion and temperature control.

Coming now to the problem of reheating slabs or billets, the continuous triple-fired furnace is arranged with a primary heating zone and a soaking zone. The primary zone has burners firing above and below the entering steel, while the soaking zone is equipped with burners above the steel only. This triple-firing rapidly heats the slab in the primary zone and temperature and surface condition are under good control in the soaking zone.

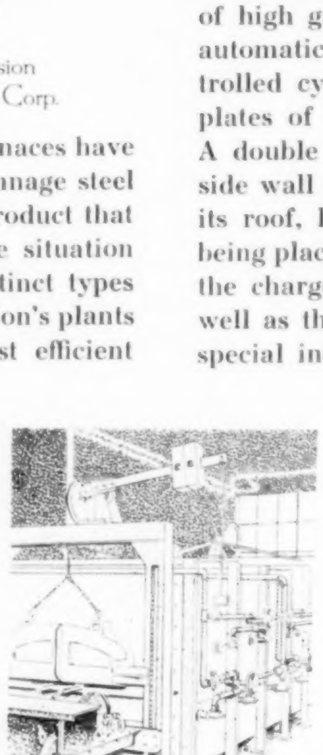
Furnaces of this type are fired with any type of fuel, but preference is given to mixed blast furnace and coke oven gas, or coke oven gas and natural gas used separately, for the reason that they constitute the most readily controlled fuels from the combustion standpoint. Very high heating rates are possible, which not only reflect good combustion design, but also necessitate proper charging and pushing mechanism in order that the steel may pass uniformly through the furnace.

Much can be said of the construction of this type of slab heating furnace, but the outstanding features are the suspended roof (which is conducive to long life), liberal use of insulation on walls and roofs, and modern burners and recuperators. These features, combined with good combustion control equipment, contribute to the uniform heating of the slab which is so essential in the rolling of strip, sheets or plate.

Heat Treating Furnaces
for Tonnage Steels

By Louis J. Rohl
Assistant Manager, Metallurgical Division
Chicago District, Carnegie-Illinois Steel Corp.

SO MANY large and interesting furnaces have been installed recently in the tonnage steel mills for the heat treatment of the product that perhaps the best way to outline the situation briefly will be to describe three distinct types which now exist in the Steel Corporation's plants in the Chicago district for the most efficient treatment of commodities requiring widely different properties.



First in point of interest as to number installed and tonnage handled are the batch type furnaces recently installed at the Gary sheet and tin plate mills. Their function is to anneal the products of the hot strip mills and the cold reduction mills. These furnaces comprise a solidly built base plate set on a permanent foundation, heavy enough to carry the desired loads and of dimensions suitable to current sheet sizes. An inner cover of light weight, corrugated, mild steel covers the charge on the base plate, its bottom edges extending into a sand seal.

Over this inner cover is placed the heavily constructed insulated outer cover containing the radiant tubes suspended either vertically or horizontally. These tubes, heated to incandescence by a gas flame circulating through them, radiate heat through the inner cover to the charge. To prevent oxidation of the steel being treated a deoxidizing gas is circulated within the inner cover. Temperatures of the radiant tubes and of the charge are automatically controlled and recorded, and the temperature difference between the outer furnace and the inner charge is held to a specified maximum after the latter has reached the desired annealing temperature. After maintaining this temperature for the prescribed time, cooling of the charge is regulated either by leaving the unit intact, or by partially or wholly removing the outer cover. Accurate control of annealing temperatures and of heating and cooling cycles has contributed markedly to the greater uniformity of quality in present day sheet products.

At South Chicago, the bell type furnaces (electrically heated) for the precision treatment of high grade carbon and alloy steels, feature automatic equipment with electrically controlled cycles of operation. Bars, shapes and plates of 30-ft. maximum lengths are treated. A double row of heating elements along each side wall of the bell cover, and a triple row in its roof, heat the charge. The side elements, being placed below the level of the grid carrying the charge, heat the load from the bottom as well as the sides and top. This, together with special insulation and sand seals, assures uniform heating of the contents of the furnace. Automatic mechanisms for loading, unloading and quenching (the latter for a predetermined length of time) are other features aimed to provide maximum control of specialty products.

Research into the properties of rails given carefully controlled treatments, led to the construction at Gary Works of a special gas fired, continuous furnace for the commercial treatment of heavy section railroad rails by the "Brunorizing" process.

This extraordinary furnace, 9½ ft. wide and 252 ft. long, provides hearth capacity for six groups of nine 39-ft. rails. It is divided into eight temperature zones, each equipped with mechanisms for controlling the quantities and proportions of gas and air for correct atmosphere. Hot rolled rails, having cooled to 1000° F., enter the furnace and progress through the various zones on oscillating rolls until they reach the maximum temperature, 1550° F., at about the middle of the furnace, the remaining half of the furnace being available to assure thorough equalization. The rails pass through the furnace under definite time cycles, varying from 18 to 30 min. depending on the mass or cross-section, and emerge at 3 to 5-min. intervals, thus providing a uniform movement of product. This carefully controlled treatment refines the grain and relieves strains, and rails so treated possess markedly improved properties as evidenced in greatly improved ductility and toughness.

It has been evident for some years that the trade requirements for many of the common "tonnage" steels cannot be met without the most accurate control of temperatures throughout the entire rolling process, extending at times

to precise heat treatments of the semi-finished and completed product. To perform these treatments accurately and continuously on the very large amount of steel going through a modern mill has required specialized equipment of extraordinary size and numbers. It is probable that progress in this direction will continue.

Electric Heating Furnaces

By P. H. Brace
Research Laboratories, Westinghouse Electric & Mfg. Co.
East Pittsburgh, Pa.

IT IS IMPOSSIBLE to discuss electric heating furnaces without constant reference to controlled atmospheres, for changes in the one have been related to improvements in the other, and vice versa. Mechanization of furnace operations has advanced rapidly, aided by improvements in the heat resisting alloys used for those parts of the mechanism subject to high temperatures. Investigations of the behavior of materials used for heating elements in controlled atmospheres carried on under the sponsorship of the American Society for Testing Materials have pointed the way to lowered resistor costs and improved performance.

New atmospheres based on the controlled combustion of hydrocarbons make it possible to produce bright, hardened steel parts from various alloy steels. At the same time decarburization has been completely eliminated. This accomplishment goes hand in hand with the development of alloy steels that may be fully hardened with inappreciable distortion by cooling in the controlled atmosphere from temperatures near 1800° F., the work coming out bright and showing Rockwell hardness between C-63 and 65 even at the surface. Great economies thus became possible in the die and tool field and special multiple chamber, muffle type heating furnaces mechanized for handling the work without interference with the atmosphere have been developed and are in use for handling pieces of considerable size.

Controlled atmospheres and special resistor materials have raised the limit of practicable working temperatures and furnaces have been designed to take advantage of these developments, such as one for general heat treating equipped with preheat, final heat and quenching chambers for operation up to 2350° F.

Certain large scale metal processing operations at high temperature and in controlled atmosphere called forth a new furnace capable of operating at approximately 2200° F. with very close temperature control. This furnace has auxiliary equipment for moving the atmosphere around a closed circuit from the furnace chamber, through a heat exchanger, purification train, electric preheater and back to the furnace. It requires some 240 kw., handles several tons at a charge and is equipped with special high alloy elements and hangers. Tap changing transformers are used for adjusting the power input.

In the ceramic field considerable work has been done under the auspices of Tennessee Valley Authority with a continuous ceramic kiln electrically heated by elements comprising a silicon carbide tube enclosing a resistor in the form of a graphite rod. A protective atmosphere is injected into the tube to protect the graphite. Temperatures up to approximately 2400° F. are attained with resistor life of a few thousand hours. The kiln proper is supplied with an atmosphere derived from controlled combustion of charcoal.

On the whole the development of electric heating furnaces reflects the growing appreciation of the advantages to be derived from controlled atmospheres and accurately scheduled heat treatment cycles. Furnaces are becoming to an increasing extent machine tools both as to structure and operating technique.

Forced Convection Heating

By C. H. Stevenson
Lindberg Engineering Co., Chicago, Ill.

FURNACES using the principle of forced convection for heating their charge are so new, relatively speaking, that it is not amiss to review the history of the development. In so doing three definitions and a basic principle should be borne in mind. The basic principle is that heat energy flows only from a higher level to a lower level, and the vigor of the transfer has some relationship to the differences in level. Hence the difficulty always experienced in heating a body mildly yet uniformly and accurately.

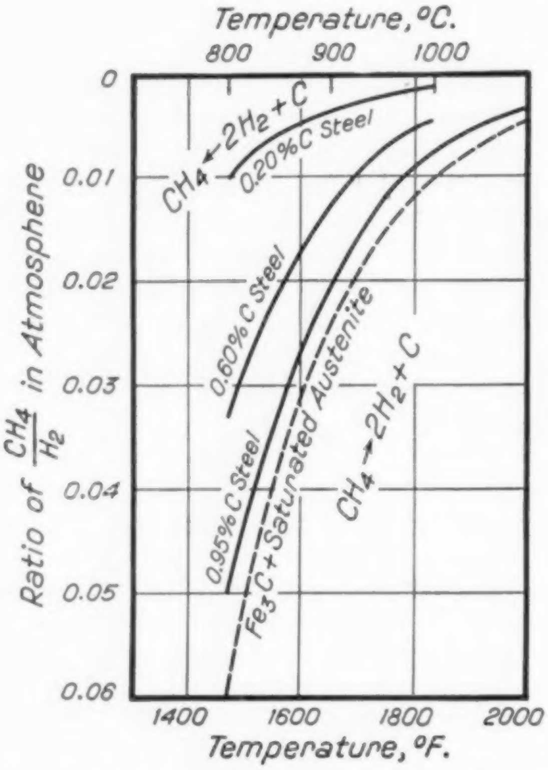
The definitions are:

Radiant heat — A method of energy transfer which follows the laws of light; travels in straight lines through air, gases or vacuum; interruptions cause shadows; can be reflected; varies as the fourth power of the temperature.

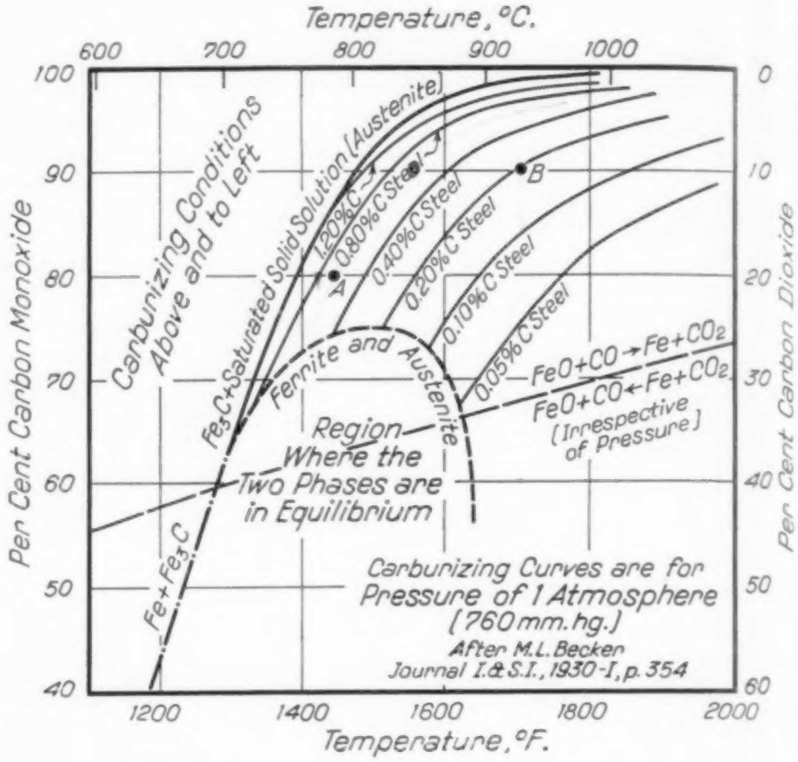
Convection heat is heat carried by air, gases

Equilibria for Gas-Steel Reactions

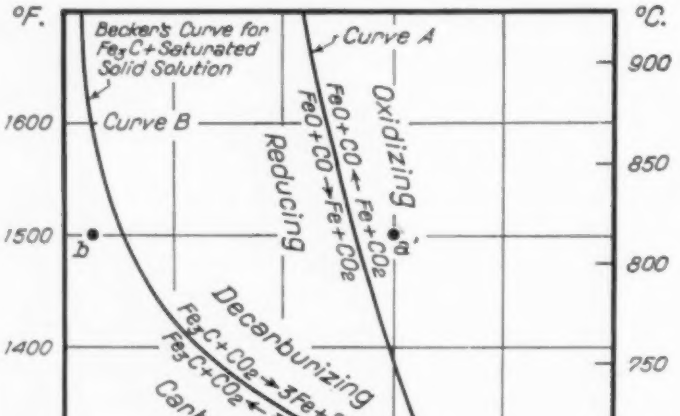
Relation Between Gas Composition, Temperature, and Carbon Content in Steel



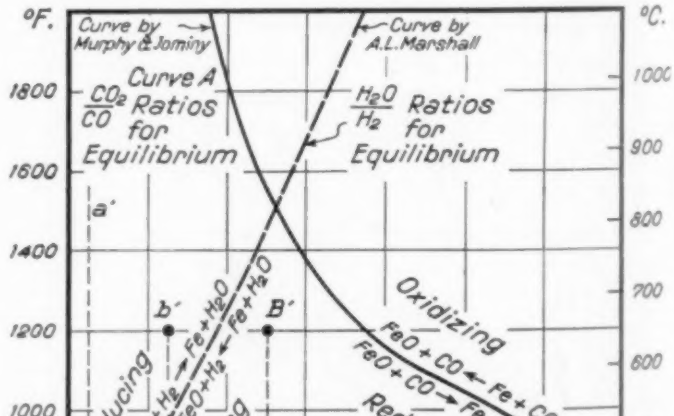
Above Curves, Adapted by Stansel From Sykes' Work, Indicate That Almost Pure H_2 Decarburizes Hot Steel (Conditions Above and Left of Corresponding Curves). Methane breaks down almost completely into carbon and hydrogen, carburizing steel (and depositing excess soot) at conditions below curves



Carburizing Reactions Depend on Carbon in Steel. Thus: 80% CO, 20% CO_2 at 1450° F., (point *A*) will carburize 0.40% C steel and lower, but decarburize 0.80% C steel and higher. However 90% CO, 10% CO_2 at 1700° F., (point *B*) is relatively inert to 0.20% C steels, will carburize lower carbon and decarburize higher carbon steels. Partial pressures, i.e., $CO + CO_2 < 100\%$, raise curves and shift to left



Action of Carbon Oxides Depends on Temperature. For instance, a dried atmosphere containing 6% CO_2 and 10% CO or ratio 0.6 (easily secured by partial combustion of fuel gas) would tend both to reduce and carburize at a 1225° F. anneal (Point *a*), but would both decarburize and oxidize at 1500° F. (Point *a'*). For "bright hardening" the CO_2 must be reduced well below Curve *B* (for instance, 1/10 the CO, as Point *b*, at 1500° F.). The above statements neglect the fact that the pressure of $CO + CO_2$ is less than 1 atmosphere



Oxidizing Action of Steam May Be Counteracted by 20 Times As Much Hydrogen (Line *a-a'*). Larger proportions of steam may scale the metal during cooling (line *b'-b*). Oxidizing — and decarburizing — propensities of moist gas may likewise be counteracted by carrying excess CO in the mixed carbon oxides present in the furnace atmosphere (for instance, $CO_2 : CO = 0.5$, or line *B-B'*, on the reducing side of curve *A*)

or liquids when circulating. Circulation is ordinarily caused by different specific weights of the fluid due to different temperatures.

Forced convection heating is the generation of heat and provision of a conveying medium to alternately pick up heat from the generator and drop off heat to the material being heated.

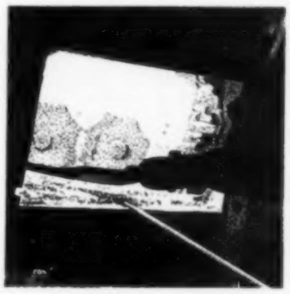
Forced convection heating is therefore "a problem in transportation".

The first low temperature heating units involved a combination of both radiant and natural convection heating. Radiant heating was found to be objectionable because it required that the parts to be heated be spread out with all surfaces in direct line with a heating source. Natural convection heating obviously caused the hottest gases to rise to the upper portion of the chamber where the roof is and the cooler gases to the bottom where the work is.

To overcome these objections, fans were installed to provide a constant movement of the circulating gases without regard to their temperature (or more accurately, their specific weight) and baffles were thrown up between the heating medium and the work to be heated to prevent direct transmission of heat by radiation. Surely this solved the problem of efficient heating to a moderate temperature — prevent radiation and stir up the atmosphere.

But blocking off the heating source resulted in piling up the heat at that point, increasing the temperature of the source to a point where radiant heat was allowed to enter the chamber either by reflection or re-radiation through the baffle. In the case of the electric furnace, increase in temperature of the heating medium decreased the life of the elements. And the stirring — while eliminating the effect of gravity — did not eliminate the natural characteristic of any moving object to take the path of least resistance. Where dense loads were being heated the air allowed itself to be stirred but developed no ambition to dig down into the dense mass. We had eliminated the effect of gravity and controlled radiation somewhat, but still weren't getting the heat to the work.

And then the problem was recognized as one of transportation — of carrying a substance (heat energy) from the point of manufacture to the point of consumption and returning for another load. If the total manufacture per hour of this substance were transported in a single trip, the difference in weight (temperature) of the conveyance going and coming would be considerable. Such calculations made it immediately evident that the greater number of trips per unit of time to transport a given quantity of this material from the place of manufacture to the place consumed would provide the least weight reduction (temperature drop) in the conveyance.



Let's take an example. Assume the burners or heating elements generating the heat have a capacity of 1000 B.t.u. per min. If the gases conveying these B.t.u.'s from the heating chamber to the work chamber make 100 revolutions (or trips) per minute, they will necessarily drop off 10 B.t.u.'s per trip and their temperature drop from the point entering the charge to the point leaving it could be figured at N degrees from a knowledge of the amount of gas in the system and its specific heat. Obviously 1000 trips per minute instead of 100 would require the delivery of only 1 B.t.u. per round trip (a temperature drop of 0.1 N), and if 10,000 trips were made per minute, each trip would require the gases traveling through the charge to cool only 0.01 N and deliver 0.1 B.t.u. A charge being heated to 800° F. under the last condition therefore would be subjected to air at exactly 800° at the top and probably not less than 799° at the bottom. No part of the charge can reach 801° and if sufficient time is permitted no part of the charge can be as cold as 798°.

When the furnace industry began to think of transportation, high speed circulation of gases was appreciated. Heat was manufactured at more distant points where danger of radiant heat whether direct or indirect was entirely eliminated, and volumes of gases at high velocities were driven in definitely defined paths back and forth between factory and consumer. The high pressure from powerful fans increased velocity even more when dense loading reduced the available path of flow.

L. A. Lindberg several years ago explained the real nature of such forced heating and its control as follows:

"No charge could be too dense, nor any part of it so located as to escape the fury of the gases lashed by the powerful electrically driven blower. Stray eddy currents from openings in the furnace shell were pounced upon and swirled away before they had the slightest opportunity to affect temperature uniformity. The problem of locating burners or elements was eliminated as heat could be bled into the circulating system at

any point away from the work chamber itself. Radiant heat from the heating medium, therefore, could not affect the temperature of the parts being heated. The high velocity of the gases tore away the film from the surfaces to be heated and shortened the heating time considerably."

By such means, in the temperature range where accurate heating had been considered most necessary, the solution was found, strangely enough, in the principles of transportation.

Gas Preparation Units

By C. G. Segeler
Industrial Gas Section
American Gas Asso., New York City

BECAUSE of the brilliant accomplishments of furnaces with specially prepared atmospheres, one is apt to forget that great tonnages of work are satisfactorily treated in direct heated furnaces provided with perfected burners and sensitive regulators. However a distinction is necessary because of the greater latitude the metallurgist has when he prepares an atmosphere in an external unit.

There are two general classes of appliances in use for preparing gas atmospheres. In the first, gas is partially burned with just enough air to produce the desired percentage of constituents and the resulting gases are passed through purifiers to remove unwanted constituents. For this function, machines must be constructed with four essential parts.

1. Gas burner permitting control of the air gas ratios at predetermined levels.

2. A suitable combustion space providing for catalytic action when this is required.

3. A washer and cooler intended to remove some of the water vapor and to cool the gas. This may also remove a part of the CO_2, SO_2, and SO_3 if present, although the low partial pressure of these constituents makes their complete removal difficult without chemical absorbents in addition to the wash water. An oxide box is often an advantage in the case of manufactured gases as it is not expensive and offers a factor of safety if the mixture is run richer than normally. Sulphur may also be better eliminated if the combustion space is maintained at a relatively high temperature — say 2200° F. or more.

4. The drier. The influence of water vapor on a finished product may be very marked and, consequently, this part of the apparatus is a most important item. Principal equipment for reducing the moisture content includes compression, refrigeration, adsorption by silica gel or by activated alumina, the latter being very successful when very low moisture content is desired.

Washing eliminates carbon particles and dust, and the resultant gas from this equipment should be non-explosive if its calorific value is kept below 50 B.t.u. per cu.ft. In common with most special atmospheres, it will contain a considerable quantity of carbon monoxide. Every precaution possible should be taken to prevent the escape of such gases into the air in the room. Ventilating hoods at loading and unloading ends, if not over the entire furnace, may be desirable.

The second type of equipment involves the principle of cracking the gas. Machines for doing this heat the unburned gas in closed containers maintained at temperatures higher than that at which the gas is ultimately to be used. The operation is generally carried out in the presence of a catalyst, such as coarse iron turnings, and steam and air may be added to remove the free carbon produced. Subsequent treatment of these gases falls along the same principles as have just been described. The cracked gases are generally higher in B.t.u. content than those from partial combustion and may be explosive in character.

In response to a demand for a gas suitable for producing a light case on small automotive parts, like wrist pins, several manufacturers have introduced units for producing gases rich in CO. The equipment functions by passing gases produced by partial combustion through a bed of incandescent charcoal. If desired, steam or water can be added to increase the hydrogen content as well. The gases so produced contain 60% combustible, chiefly carbon monoxide and hydrogen. CO_2 may also be removed from cracked gas or partially burned gas by chemical reaction with caustic (a rather expensive process) or by absorption in a suitable organic chemical, which can later be regenerated. In any event CO_2 absorbers add materially to the cost and complexity.

Without minimizing the improvements that have been made in the equipment, these have been less significant than the increase in numbers of applications. The adoption of equipment for automatically controlling the setting of special atmosphere units so as to maintain the composition of the finished gas within narrow, predetermined limits is another growing application of interest to the metal industry.

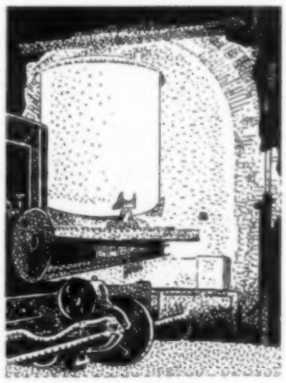
Atmosphere Furnaces

By Matthew H. Mawhinney
Consulting Engineer, Fuels and Furnaces
Salem, Ohio

THE PURPOSE of this brief discussion is to trace the major developments in furnaces using controlled atmosphere for the heating of metals, particularly as they apply to probable developments in the immediate future.

Special atmospheres are used to control the changes which occur in a metal as the result of usual heating. This may be a chemical change as a loss of carbon in steel (decarburization) or it may be a physical change resulting from the chemical oxidation of the metal. In the latter instance, the control may involve only the prevention of loose oxide or scale (clean heating) or it may involve the maintaining of a chemically clean surface in unchanged form (bright heating).

Original experiments were conducted with hydrogen, mixtures of hydrogen and nitrogen, and other elemental gases in sealed retorts with the product. These gases were made by electrolysis or from dissociated ammonia and were rather expensive. Then followed the cracking of hydrocarbon gases, first successful about 1930 with the development of catalysts in the generators, and these gases were applied in electric furnaces which by special construction became the gas containers, frequently making retorts or muffles unnecessary. These atmospheres were successful in clean and bright annealing of steel but did not control loss in carbon from the surface layers. The development of satisfactory driers increased the range of metals amenable to bright annealing and assisted in the control of carbon. Further investigation on the effect of various gases on carbon steels developed the fact that carbon dioxide must also be removed, and after several attempts with costly removal methods, an apparatus has recently been developed to accomplish this in a satisfactory manner.



Utilization of atmospheres with a considerable amount of hydrocarbon gas has commercialized the process of gas carburization in contradistinction to pack carburization. Such atmospheres build up a conductive mass of soot on electrical resistors, leading to grounds or short circuits, so this work has usually been done in muffle furnaces. Development of fuel fired radiant tubes, as a substitute for electric heating elements, will probably enable continuous carburization to be done in a furnace without a muffle. In many types of furnaces the choice between electric resistors and radiant tubes is a matter of costs, as comparable results are obtained with the two methods of heating.

The protective atmosphere furnace has made rapid progress and has penetrated many new fields, including bright hardening of many steel products, bright brazing, short cycle annealing of malleable iron without pots, and bright and clean annealing of all kinds of nonferrous products. Some of these items are the subjects of articles elsewhere in this magazine.

The bright brazing furnace is one of the most interesting developments and well illustrates the possibilities which are opened up by the use of protective atmosphere. The temperatures required for brazing are too high for electric elements in the usual furnace, but with the protection of the atmosphere continuous operation at 2100° F. is maintained without difficulty. The same thing applies to conveying methods, because even alloys in cast form have a short life at these temperatures in the usual furnace atmosphere, while with the protective gas the usual conveyor in brazing furnaces is a belt of woven alloy wire of small diameter. Some difficulties have been met wherein carbon has deposited in spongy or slightly loose structures in the heat resisting castings, causing early failure. The cure has been sought in better foundry practices.

Development in the immediate future requires a more detailed and more widespread knowledge of the effect of different gas combinations on the chemical analysis of steel, particularly the carbon content. As this knowledge is developed and followed by simplified generator equipment for producing the right gas combination for specific applications, the new method of heating will be more widely adopted to control decarburization.

There is also every indication that protective gas furnaces for clean and bright heating will be more universally applied. With an increasing demand for an improved surface on rod, wire, tube, and other products, the greater cost of protective heating will be justified.

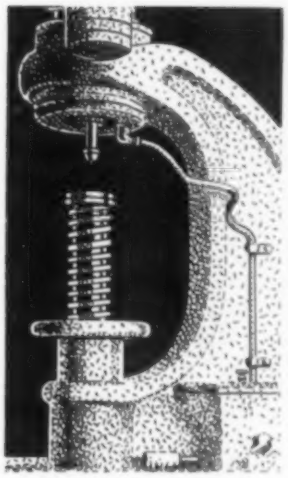
TESTING

AND

CONTROL

INSTRUMENTS

Testing and Control Instruments



Radiation Pyrometers

By P. H. Dike
Assistant Director of Research, Leeds & Northrup Co.
Philadelphia

FOR MANY YEARS, the radiation pyrometer was taboo in most industrial plants, either because of unfortunate experience with such instruments, or because of prejudice based on the reported experiences of others. During the past five years, however, a change in attitude has taken place and modern radiation pyrometers are now in use in a considerable number of selected applications. In a variety of heat treating, metal working and ceramic processes they are measuring the temperatures of baths and streams of molten metal, of billets, of rails and rods, of cement-kiln linings, of furnace roofs, and of work in process — certainly an imposing list of difficult situations.

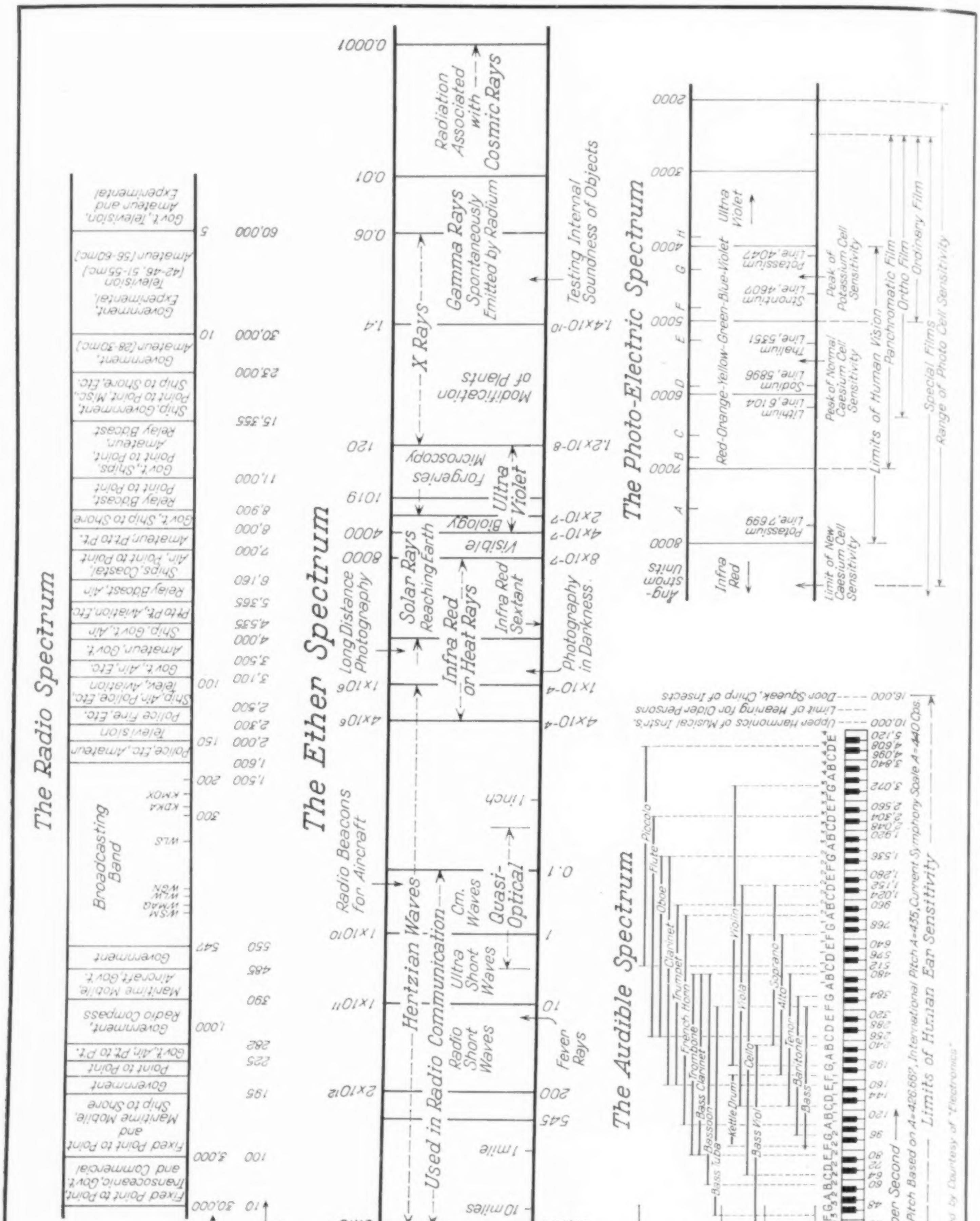
The advance in the adoption of radiation pyrometers is due to a number of factors. Consistent studies, based on scientific analysis and plant tests, have progressively singled out industrial applications in which anticipated benefits have been fully realized in practice. Many problems, which at first seemed impossible, have been solved by a modification of instrument or mounting. Mechanical designs and optical systems have been improved. Instead of attempting to make one device serve every purpose, industry's needs have been studied, and designs have been diversified to furnish the type of detecting device best fitted to each job. As a result, modern radiation pyrometers have set a remarkable record for ruggedness, speed and reliability.

Radiation pyrometers are now available for the recording of temperatures as high as 5000° F. They may average the temperature of several square feet of furnace roof, or measure the temperature variations of an eighth-inch wire. They may record the temperature of a billet which remains in view for as little as two seconds, or may be slowed down to damp out temperature fluctuations which, in the operation of automatic control, are unimportant or undesirable. Because of longer life and freedom from contamination, radiation devices are replacing platinum thermocouples for a number of high temperature measurements. In certain applications, they detect with greater sensitivity and speed, operate more reliably than either base metal or platinum couples. Where temperatures are too high for base metal couples, where atmospheres are injurious to couples, or where temperature is desired of objects which are moving or are otherwise inaccessible, the radiation pyrometer may be quite applicable.

Thermocouples and Protection Tubes

By G. R. Fitterer
University of Pittsburgh

NO NEW thermoelectric materials have been announced within the past year. Some interesting research work is under way, however, concerning the characteristics of some of the base metal couples. The solubility of vari-


The Radio Spectrum
The Ether Spectrum
The Audible Spectrum
The Photo-Electric Spectrum
Long Electric Waves
Hertzian Waves
Used in Radio Communication
Infra Red or Heat Rays
Solar Rays Reaching Earth
X Rays
Gamma Rays Spontaneously Emitted by Radium
Radiation Associated with Cosmic Rays
Limits of Human Ear Sensitivity
Limits of Human Vision

ous industrial gases in these materials has presented a problem of maintenance of calibration and life of the couples, particularly at the higher temperatures. Some thorough study of these disturbing factors has certainly been in order and at least one instrument company is making a comprehensive survey of the subject.

In Germany, the tungsten-molybdenum thermocouple which was patented by Morsing in 1923, has been revived by Osann and Schröder and by Leiber, as evidenced by publications in *Archiv für das Eisenhüttenwesen.* These authors claim good measurements for liquid steel temperatures, although this combination has been tried in several places in this country and discontinued because of its very low thermoelectric potential and its ease of contamination by the carbonaceous gases.

A silicon carbide tube was used by the German scientists to protect the couple from slag and metal, although it has been this author's experience that silicon carbide dissolves very rapidly in liquid steel and is easily attacked by basic slags.

The carbon vs. silicon carbide thermocouple which was developed recently is now being used successfully in numerous types of liquid metallurgical applications. Here, however, the carbon is the outer element and the silicon carbide the inner. The carbon is painted with a refractory wash which protects it against slag and metal. In one application as many as 160 immersions have been obtained before any parts required replacement.

In this connection numerous refractory washes have been developed for the different requirements. For example, liquid Hadfield manganese steel with a basic electric furnace slag is very erosive to most refractory materials. However, one has been developed which protects the couple satisfactorily.

Basic openhearth rimming steel presents a problem which has not yet been solved. Here the slag is basic but very high in iron oxide — very highly erosive. Developments are expected in this field shortly however.

This refractory wash idea has been developed by another company for protection tubes for base metal couples. The wash is painted on and seems to adhere with sufficiently close bond to protect the metal tube satisfactorily.

Another recent development in protection tubes has been through variations in the analysis of the heat resisting chromium-nickel alloys. This has been studied by one of the instrument companies and it now supplies four different types of alloy tubes.

One of these is useful for sulphurous gases up to 2000° F. and the others are for carbonaceous gases and various types of salt baths such as chlorides, nitrates, and cyanides. These are useful at 2200 and 1850° F. respectively. Another metallic tube has a very high heat conductivity and gives a quick response to changes in temperature.

Further developments along these various lines are to be expected. The trend is now very definitely in the direction of finding a material that will unquestionably work well in one specific job rather than a super-material that may be universally applicable.

Optical Pyrometers

By W. E. Forsythe
Lamp Development Laboratory, General Electric Co.
Nela Park, Cleveland

As IS WELL KNOWN, an optical pyrometer is a device for measuring the temperature of a hot body by matching its brightness with that of some comparison source. Many workers prefer a lamp filament for this comparison source, located at the focus lens of a telescope through which the object is observed through a monochromatic screen (generally a red glass). By varying the current through the filament, brightness can be accurately matched.

Such a "disappearing-filament optical pyrometer" is calibrated by measuring the currents through the pyrometer filament for a series of brightness matches with a blackbody, at a number of definite temperatures, observed through the optical pyrometer. A special lamp with a sufficiently large filament operated at a measured current may be substituted for the blackbody provided the brightnesses of the lamp filament correspond to definite temperatures of the blackbody.

Optical pyrometers are generally used to

measure the temperature of furnaces where approximately blackbody conditions exist. However, it is often convenient to study non-blackbodies with an optical pyrometer and assign temperatures to a brightness of a non-blackbody as if it were a blackbody. The difference between brightness temperature and true temperature depends upon the wavelength interval used and the substance studied, and varies from a few degrees for untreated carbon to about 200° C. for polished platinum at its melting point.

It is often necessary to measure temperatures higher than that for which the pyrometer filament has been calibrated. This is done by using an absorbing glass between the pyrometer filament and the source studied to cut down its apparent brightness. From the transmission of the absorbing screen and the characteristics of the red glass in the eyepiece, the amount the screen extends the temperature scale can be calculated.

The best results with this type of pyrometer require a good lamp bulb and filament and a good optical system, well lined up. Some consideration should also be given to the screens used, both to obtain approximately monochromatic radiation and to reduce the apparent brightness of the source studied when it is at very high temperatures. The results depend also upon the calibration and upon the accuracy obtained and kept in measuring the current through the pyrometer filament.

Several years ago extensive studies showed that the pyrometer filament should be well lined up in the center of the field and that certain relations were necessary between the resolving power of the eyepiece and the entrance cone of rays falling upon the pyrometer filament. These relations were found necessary because the difraction around the filament which, unless the proper conditions were met, gave dark and bright streaks along the filament. If these streaks were visible, it was found very difficult to make accurate brightness matches between the comparison source and the source being studied. These same investigations showed that a good optical system which includes a very clear bulb for the pyrometer lamp (plain glass windows are much better) is necessary for the best results. These conditions have been well met in new pyrometers recently placed on the market.

Investigations seem to show that a ribbon pyrometer filament offers some advantages. Furthermore, too short a filament will introduce errors due to changes in the ambient temperature — probably dependent upon the end losses in the pyrometer filament.

Further developments will probably result in smaller and more easily operated pyrometers.

Electron Tubes
in Recorders and Controllers

By C. O. Fairchild
Director of Research, C. J. Tagliabue Mfg. Co.
Brooklyn, N. Y.

SEVEN YEARS AGO this month, METAL PROGRESS printed an editorial entitled, "Why Not Use Vacuum Tubes in Pyrometers", and the answer was that it was too difficult to amplify the small direct current generated by the thermocouple with enough accuracy so the result could be used to indicate temperature directly, and that mechanically driven measuring instruments then available were more accurate than the thermocouple anyway.

Seven years is a long time, and the situation today is vastly changed. Even in 1931 the pioneering "Speedomax" was under commercial trial, a recording machine in which speed and not cost was the important item. It was a successful equipment for recording the temperature of steel passing through fast continuous mills, and did so by amplifying the current from a thermocouple to control a reversible motor instead of a galvanometer. Electron tubes began to be used in temperature recorders and controllers designed for the ordinary speeds of operation when the cost of these elements reached a sufficiently low figure. Today they are found in temperature measuring instruments such as the "Celectray" in conjunction with phototubes, mirror galvanometers and special relay devices for control purposes.

While the speed of the last mentioned is somewhat higher than former mechanically operated recorders, the main difference lies in the substitution of a photo-electric method of balancing a potentiometer for the older mechanical method — that is, the recorder

became for the most part an electrically driven instrument instead of mechanically driven. The use of a mirror galvanometer to take the place of one having a metal boom or pointer permitted these higher speeds. Approximately coincident with the early marketing of the first photo-electrically balanced recorder an indicating controller was put on the market consisting essentially of a potentiometric measuring circuit, a light source, mirror galvanometer, phototube, amplifier tube and electromagnetic relay. This device proved to be the most sensitive on the market in its class.

Three or four years ago a successful recording optical pyrometer, the "Optimatic", appeared in which a phototube was used as a receiver of visible radiations and the current so excited amplified and used to operate a recording milliammeter. Then along came the "Instagraph" in which a thermocouple is directly connected into the grid circuit of an amplifier tube and through the use of a mirror galvanometer and phototube in this circuit the amplified current is made to vary with the potential of the thermocouple. The plate current is conducted into a recording milliammeter.

In these instruments no use is made of the conventional or classical methods of thermoelectric pyrometry. Our own contribution rests in an adaptation of the conventional recorder into one of extremely high speed. The fact that the more simple instrument is adaptable is only another example found repeatedly in other developments — that is, the first developments are more complicated than those following.

Warranting mention is also a new throttling electric controller in which a screen between the galvanometer and phototube slowly oscillates to turn on power at recurring intervals inversely proportional to the temperature. This controller is certainly by far the most sensitive ever offered to furnace users.

A recurring question is the relative ruggedness as compared to mechanical devices. The common familiarity with home radio receivers should dispel any notion that electron tubes are too fragile for industrial measuring instruments. The fact of the matter is that they have already proved to be very reliable, provided the applied voltages are adjusted for long life. Even though instruments have been on the market for a number of years we cannot yet determine the average life of any of the electron tubes. Some instrument makers use standard radio tubes in their instruments, but it is better policy to pay a premium for special, tested tubes. Replacements are so seldom there is no difficulty here.

Again comparing the present situation with that seven years ago, it may be said that electron tubes are now very useful not only in amplifying the current from thermo-junctions but also in replacing mechanisms for recording and control. These new devices are not only ten-fold faster than the old, but have also been of aid in meeting the demand for increased accuracy. Undoubtedly the future will see substitutions of electronic devices for many moving parts.

Meters & Control Valves

By J. W. Beecher
Development Engineer, The Bristol Company
Waterbury, Conn.

TODAY, more than ever before in the history of modern industry, it is generally recognized that the margin between profit and loss is exceedingly narrow. For this reason, waste, leakage, lost time, inefficient process operations, variable quality in products and rejections must be reduced to a minimum.

In overcoming these troublesome enemies to industry, the accurate measurement and control of gases, fluids and steam offers almost unlimited possibilities. Flow meters are valuable in governing and accounting for gases or fluids consumed in industrial plants, and in many instances they have brought out, in bold relief, facts about hidden losses and unsuspected defects in plant operations.

Flow meters usually consist of a primary element, which produces a differential pressure and a secondary element which transposes this differential pressure into units of flow and records or indicates the rate of flow.

The primary element is a constriction in the pipe line through which the medium is flowing, such as an orifice plate, venturi tube or flow nozzle. Acting in accordance with one of the laws of hydraulics, the primary element creates a differential pressure between the up-stream and down-stream side of the constriction and the rate of flow varies with the square root of this differential pressure.

The above facts are fundamental regarding the measurement of flow. For the secondary element, various types of instruments are used to measure the differential pressure produced by the primary element and it is these that the instrument manufacturer is continuously improving. A very reliable device consists of

Sheet I of 3

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No 1, British Institute of Metals

Element (Atomic No.)	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio $c \div a$	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group IA in Periodic Sequence									
3 Lithium	(2)1	⧉	—	8	3.51±0.04	—	3.04	—	3.13
11 Sodium	(2)(8)1	⧉	—	8	4.30±0.04	—	3.72	—	3.83
19 Potassium	(2)(8)(8)1	⧉	—	8	5.333_5	—	4.618	—	4.76
37 Rubidium	(2)(8)(18)(8)1	⧉	—	8	5.62±0.03 at -173°C.	—	4.87 at -173°C.	—	5.02
55 Cesium	(2)(8)(18)(18)(8)1	⧉	—	8	6.05±0.03 at -173°C.	—	5.24 at -173°C.	—	5.40
87 Virginium	(2)(8)(18)(32)(18)(8)1	—	—	—	—	—	—	—	
Group IB									
29 Copper	(2)(8)(18)1	⊡	—	12	3.607_8	—	2.551_1	—	2.551
47 Silver	(2)(8)(18)(18)1	⊡	—	12	4.077_8	—	2.883_5	—	2.883
79 Gold	(2)(8)(18)(32)(18)1	⊡	—	12	4.069_9	—	2.877_8	—	2.877
Group IIA in Periodic Sequence									
4 Beryllium	(2)2	⬡	1.584_8	6,6	2.267_9	3.594_2	2.223_5	2.267_9	2.25
12 Magnesium	(2)(8)2	⬡	1.6236	6,6	3.202_2	5.199_1	3.190_0	3.202_2	3.20
20 Calcium	(2)(8)(8)2	α = ⊡	—	12	5.56	—	3.93	—	3.93
(data for 450°C.) →		β = ⬡	1.640	6,6	3.94	6.46	3.94	3.955	3.98
38 Strontium	(2)(8)(18)(8)2	⊡	—	12	6.07_5	—	4.29_6	—	4.29_6
56 Barium	(2)(8)(18)(18)(8)2	⧉	—	8	5.01_5	—	4.34_3	—	4.48
88 Radium	(2)(8)(18)(32)(18)(8)2		—	—	—	—	—	—	—
Group IIB									
30 Zinc	(2)(8)(18)2	⬡	1.8560	6,6	2.659_0	4.935_1	2.659_0	2.906_1	2.748
48 Cadmium	(2)(8)(18)(18)2	⬡	1.885_2	6,6	2.973_6	5.606_9	2.973_6	3.287_2	3.042
80 Mercury	(2)(8)(18)(32)(18)2	▱	α = 70°31.7′	6	2.999 ← at -46°C.		2.999	—	3.10
Group IIIA in Periodic Sequence									
5 Boron	(2)3		—	—	—	—	—	—	2.80 to 2.86 (note b)
13 Aluminum	(2)(8)3	⊡	—	12	4.041_4	—	2.856_8	←	
21 Scandium	(2)(8)(9)2		—	—	—	—	—	—	
39 Yttrium	(2)(8)(18)(9)2	⬡	1.588	6,6	3.66_3	5.81_4	3.59_5	3.66_3	3.62_9
57 Lanthanum	(2)(8)(18)(18)(9)2	α = ⬡	1.613	6,6	3.75_4	6.06_3	3.72_7	3.75_4	3.741
		β = ⊡		12	5.29_6		3.754		3.745
89 Actinium	(2)(8)(18)(32)(18)(9)2		—	—	—	—	—	—	—
Group IIIB									
31 Gallium	(2)(8)(18)3	▯	—	—	4.5167	7.6448	(note c)	—	—
		a÷b÷c = 1:0.99868:1.69257			b = 4.5107				
49 Indium	(2)(8)(18)(18)3	◬	1.077	4,8	4.58_3	4.93_6	4 at 3.24_1	8 at 3.36_8	3.138
81 Thallium	(2)(8)(18)(32)(18)3	α = ⬡	1.60_0	6,6	3.45_0	5.52_0	3.40_4	3.45_0	3.427
		β = ⊡	—	12	4.84_1	—	3.42_3	—	3.42_3

Notes: (a) ⧉ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close packed hexagonal; ▱ is simple rhombohedral; ▯ is orthorhombic; ◬ is face-centered tetragonal

(b) Appears to be smaller in some alloys

(c) 8 atoms to unit cell; each atom has 1 neighbor at 2.43_7, 2 at 2.70_6, 2 at 2.73_6 and 2 at 2.79_5

a mercury manometer or U-tube, the two legs having enlarged diameters at top, and these carry check valves and floats on the up-stream and down-stream sides respectively. The float is hinged to a pen-arm shaft, and as the surface of the mercury rises or falls in response to changes in rate of flow, it moves a recording arm correspondingly.

From a technical standpoint, there are certain important items to be considered in the selection of primary and secondary devices. Calculations for the inside diameter of the primary device should be based on common information such as data and equations published by the American Gas Association or the American Society of Mechanical Engineers, in order that anyone may be able to check the orifice size and differential pressure used with any meter, provided the need for such checks should arise. The secondary device should consist of few moving parts and these should be sturdy beyond liability of damage when cleaning the meter — periodically necessary to obtain best operation of the meter. Outside adjustment for damping should also be available. No calibration should be necessary during the life of the meter.

In addition to recording the rate of flow, a third element may be introduced for the purpose of automatically controlling the rate of flow and to indicate or record the same. The controlling element should be designed so that no biasing force will impede the action of the meter. The difference in pressure at the venturi in the pipe line is entirely insufficient to actuate a control valve in the pipe line itself, and the pressure differential must therefore be amplified. Numerous devices are available, at least in principle, but one very satisfactory one utilizes an auxiliary source of 15-lb. compressed air. A small thin vane is actuated by the secondary element of the flow meter and this vane passes midway between two opposing air jets. When the vane is not interposed there is insufficient back pressure to operate the main control valve.

As the flow reaches the control point, the meter moves the vane between the opposed jets an amount sufficient to restrict the flow of air through the jets, and pressure to the diaphragm valve top builds up and is maintained, holding it in the control position until there is a change in the controlled flow.

The diaphragm valve used for flow proportioning should operate without hysteresis, and should be designed so that any percentage of stem travel should cause the same percentage of flow change. The seats should be designed to prevent wire drawing and the whole valve made of material to resist corrosion.

Another interesting advancement is the application of telemetering principles to the remote recording and controlling of flow. An electric flow meter is one outcome of these developments. Flow meters are also available for pneumatically telemetering to remote points for recording, or recording and controlling. Totalizers have also been worked upon extensively; mechanical and electrical integrators have been developed, the latter being found as the latest advancement in this particular phase.

Another refinement has resulted from work done in static pressure compensation. As the demands for closer control in process manufacturing increase it is reasonable to assume that the measurement and control of flow will demand the automatic compensation of temperature, pressure, vapor content and specific gravity, according to the flowing medium.

Instruments equipped with features to handle some of these factors are already in the process of development. For the future we look forward to many useful developments and applications for instruments of this type.

Atmosphere Analyzers

By A. E. Krogh
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The Brown Instrument Co., Philadelphia

REALIZATION of the importance of furnace gas compositions by men in the metal working industries has been the direct cause of much recent development in automatic gas analyzers and methods of control. This refers to the analysis and control of atmospheres inside the furnace, bathing the work being treated, rather than the analysis of flue gases for the control of combustion — a much better perfected art.

Hand operated chemical analyzers were satisfactory for the early tests and developments when atmospheres were not considered as critical as they are now, but intermittent hand operation is too slow for modern practices. Even when attended by one man continually they could only give results at intervals, and the labor and maintenance costs render that method impractical anyway. Automatic measuring and recording instruments are clearly the answer, for to control anything one must first measure the quantity.

Automatic gas analyzers can roughly be

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No. 1, British Institute of Metals

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio $c \div a$	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group IVA in Periodic Sequence									
22 Titanium	(2)(8)(10)2	⬡	1.601	6,6	2.95_3	4.72_9	2.91_5	2.95_3	2.93
40 Zirconium	(2)(8)(18)(10)2	α=⬡	1.589	6,6	3.22_3	5.12_3	3.16_6	3.22_3	3.19
(data for 867°C.)		β=⊞	—	8	3.61	—	3.12_6	—	—
72 Hafnium	(2)(8)(18)(32)(10)(2)	⬡	1.587	6,6	3.20_0	5.07_7	3.13_9	3.20_0	3.17
90 Thorium	(2)(8)(18)(32)(18)(10)(2)	⊡	—	12	5.07_7 or 5.09_1	—	3.590 or 3.600	—	—
Group IVB, Including Carbon and Silicon									
6 Carbon, diamond	(2)4	◊	—	4	3.5606	—	1.5113	—	—
graphite	—	⬡ (b)	2.75	6	2.46	6.78	1.42	2.46	—
14 Silicon	(2)(8)4	◊	—	4	5.41_8	—	2.34_6	—	—
32 Germanium	(2)(8)(18)4	◊	—	4	5.64_7	—	2.44_5	—	2.788
50 Tin, gray	(2)(8)(18)(18)4	◊	—	4	6.46	—	2.797	—	3.164
white	—	Δ	0.5456	4,2	5.8194	3.1753	3.0161	3.1753	—
82 Lead	(2)(8)(18)(32)(18)4	⊡	—	12	4.9389	—	3.4923	—	3.494
Group VA in Periodic Sequence									
23 Vanadium	(2)(8)(11)2	⊞	—	8	3.033	—	2.62_7	—	2.69
41 Columbium	(2)(8)(18)(12)1	⊞	—	8	3.29_4 ±0.001	—	2.853	—	2.94
73 Tantalum	(2)(8)(18)(32)(11)2	⊞	—	8	3.298 ±0.002	—	2.854	—	2.94
91 Protoactinium	(2)(8)(18)(32)(18)(11)2		—	—	—	—	—	—	—
Group VB									
7 Nitrogen	(2)5	α=cubic	—	—	5.66	—	1.06	—	—
15 Phosphorus	(2)(8)5	▱	α=34° 7′	3,3	5.14	—	1.74	3.01	—
33 Arsenic	(2)(8)(18)5	▱	α=53°49′	3,3	4.151	—	2.508_6	3.146_5	—
51 Antimony	(2)(8)(18)(18)5	▱	α=57° 5′	3,3	4.497	—	2.879	3.378	3.228
83 Bismuth	(2)(8)(18)(32)(18)5	▱	α=57°16′	3,3	4.736_5	—	3.105	3.474	3.64
Group VIA in Periodic Sequence									
24 Chromium	(2)(8)(13)1	α=⊞	—	8	2.878_6	—	2.492_9	—	2.57
		β=⬡	1.626	6,6	2.71_7	4.41_8	2.709	2.717	2.71
42 Molybdenum	(2)(8)(18)(13)1	⊞	—	8	3.140_3	—	2.719_6	—	2.80
74 Tungsten	(2)(8)(18)(32)(12)2	α=⊞	—	8	3.158_3	—	2.735_2	—	2.82
		β, (c)	8 atoms in unit cell →		5.038		2.519	2.816	
92 Uranium	(2)(8)(18)(32)(18)(12)2	Monoclinic	a÷b÷c=1÷1.73÷1.17 β=64°18′		2.829	3.308	2.829 ←	Note d	—
					b=4.887				
Group VIB									
8 Oxygen	(2)6	—	—	—	—	—	—	—	—
16 Sulphur	(2)(8)6	▯ (d)	2.31_5	—	10.61	24.56	—	—	—
34 Selenium	(2)(8)(18)6	⬡ (e)	1.140	2,4	4.337	4.945	2.316	3.457	—
52 Tellurium	(2)(8)(18)(18)6	⬡ (e)	1.33	2,4	4.445	5.912	2.858	3.46	—
84 Polonium	(2)(8)(18)(32)(18)6	—	—	—	—	—	—	—	—

Notes: (a) ⊞ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close packed hexagonal except as noted; ◊ is diamond; Δ is tetragonal; ▱ is rhombohedral and ▯ is orthorhombic

(b) Graphite is hexagonal, not close packed, with four atoms per unit cell.

(c) Cubic structure; two positions distinguishable, X and Y. Each atom X has 12 Y at 2.816 Å; each atom Y has 2 Y at 2.519 and 4 X at 2.816 Å

(d) 128 atoms in unit cell. Data from International Critical Tables or A.S.M. Metals Handbook

(e) Hexagonal, not close packed; each atom has 2 neighbors at d_1 and 4 at d_2

divided into three classes — chemical, electrical, and mechanical. The first type in its most common form is a mechanically driven Orsat type of analyzer, capable of measuring the proportion of CO_2. Another form depends upon catalytic combustion of unburned gases, while still others utilize other appropriate reactions.

The second or electrical type is operated on the principle that many gases differ in thermal conductivity, and when this quality of a gas mixture is measured, the proportion of a given gas present may be estimated. The method is very advantageous for many problems. It can be made very fast and accurate, and maintenance is less than on some other forms.

Mechanical types of automatic gas analyzers are available in a number of forms, but operate generally upon the principle that many gases differ in densities. Some measure this quality directly by weighing a column of gas, while others measure it indirectly from the kinetic energy of the gas in motion.

The requirements of metallurgical processes differ greatly, and each must be studied to determine the quantity it is desired to measure. In hardening processes, for instance, it is desirable to measure the three ratios $CH_4 : H_2$, $H_2O : H_2$, and $CO : CO_2$. Since no instruments are today available for measuring any one of these, much less all three of them, it is necessary to select an instrument that will directly show the state of equilibrium in the furnace, and which experience has proved valuable. A form of the electrical type analyzer is being used on a large number of steel treating furnaces with remarkable success. On the other hand, in bright annealing of copper, the atmosphere desired generally contains only small quantities of unburned gases, and the thermal conductivity is not a suitable measure; chemical analyzers of the combustion type have proved useful here.

Where several types of analyzers will serve the purpose, consideration should be given to speed of response, maintenance problems, accuracy, and costs.

Automatic control of gas analysis is being successfully applied on many processes. For such applications, prime requirements are that the analyzer be continuous, extremely fast in its response, and free from sampling errors.

The progress of automatic gas analyzers in the ferrous industries is very similar to that of pyrometers some years ago. Temperature indicators, recorders, or controllers are now known to be essential parts of any furnace. While gas analyzers will not find as wide an application, it is safe to prophesy that in all instances where furnace atmospheres are important, there automatic gas analyzers will eventually be required just as pyrometers are now.

Physical Testing

By Harry D. Churchill
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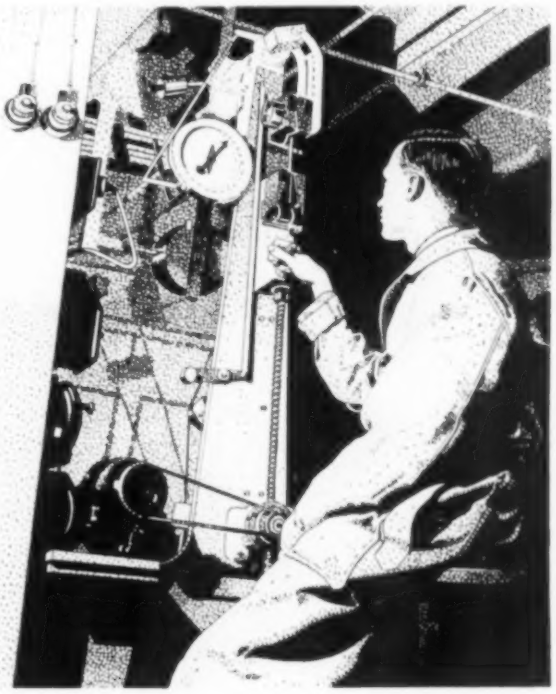
PHYSICAL testing covers such a diversified field that in this space it must be limited to metals only, and still further to its use with standardized specimens, thus neglecting the testing of a material in unusual shape such as a gear and its use in determining the action of materials in a completed structure.

The tension test still is the most universally used of all test methods, but one item is worthy of comment: Outside of the immediate circle of those directly connected with physical testing there seems to be a lack of differentiation between "proportional elastic limit", "elastic limit", "yield point" and "yield stress". Lack of precision in the use of these terms sometimes causes difficulties in interpreting and meeting specifications. Since there are thousands of useful metals and alloys, most of which do not have a distinct "yield point", an agreement as to "yield stress" would be desirable. The deter-



Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No. 1, British Institute of Metals

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio $c \div a$	Coordination No.	Lattice Constant		Interatomic Distance		Atomic Diameter (Coordination No. 12)
					a	c	d_1	d_2	
Group VII A in Periodic Sequence									
25 Manganese	(2)(8)(13)2	α = Cubic (note b)		—	8.894	—	—	—	—
		β = Cubic (note c)		12	6.300	—	—	—	—
43 Masurium	(2)(8)(18)(14)1	—	—	—	—	—	—	—	—
75 Rhenium	(2)(8)(18)(32)(13)2	⬡	1.614_8		2.755_3	4.449_3	2.734_9	2.755_3	2.75
Group VII B									
9 Fluorine	(2)7	—	—	—	—	—	—	—	—
17 Chlorine	(2)(8)7	—	—	—	—	—	—	—	—
35 Bromine	(2)(8)(18)7	—	—	—	—	—	—	—	—
53 Iodine	(2)(8)(18)(18)7	▯	a÷b÷c = 1÷1.51÷2.04		4.795	9.780	2.70	(note d)	—
					b = 7.255				
85 Alabamine	(2)(8)(18)(32)(18)7	—	—	—	—	—	—	—	—
Group VIII in Periodic Sequence									
26 Iron	(2)(8)(14)2	α = ⧉	—	—	2.861_0	—	2.477_7	—	—
		γ = ⊡	—	—	3.64 ← at 900°C.		2.58_0	—	2.52
27 Cobalt	(2)(8)(15)2	α = ⬡	1.624	—	2.50_7	4.07_2	2.49_9	2.507	2.50
		β = ⊡	—	—	3.54_5	—	2.507	—	2.507
28 Nickel	(2)(8)(16)2	α = ⬡	1.64	—	2.49	4.08	2.49	2.49	2.49
		β = ⊡	—	—	3.517_0	—	2.486_9	—	2.487
44 Ruthenium	(2)(8)(18)(15)1	⬡	1.585	—	2.69_5	4.27_3	2.64_3	2.69_5	2.67
45 Rhodium	(2)(8)(18)(16)1	⊡	—	—	3.795_5	—	2.683_8	—	2.684
46 Palladium	(2)(8)(18)(18)-	⊡	—	—	3.882_4	—	2.745_3	—	2.745
76 Osmium	(2)(8)(18)(32)(14)2	⬡	1.578	—	2.730	4.309	2.669	2.730	2.70
77 Iridium	(2)(8)(18)(32)(15)2	⊡	—	—	3.831_2	—	2.709_1	—	2.709
78 Platinum	(2)(8)(18)(32)(16)2	⊡	—	—	3.915_8	—	2.768_9	—	2.769
Rare Earth Group									
58 Cerium	(2)(8)(18)(19)(9)2	α = ⬡	1.62	6,6	3.65	5.91	3.63	3.65	3.64
		β = ⊡	—	12	5.14_3	—	3.63_7	—	3.63_7
59 Praseodymium	(2)(8)(18)(20)(9)2	⬡	1.620	6,6	3.657	5.924	3.63_8	3.657	3.65
60 Neodymium	(2)(8)(18)(21)(9)2	⬡	1.608	6,6	3.65_7	5.88	3.61_9	3.65_7	3.64
68 Erbium	(2)(8)(18)(29)(9)2	⬡	1.63	6,6	3.74	6.09	3.73	3.74	3.73

Notes: (a) ⧉ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close-packed hexagonal; ▯ is orthorhombic

(b) Approximates ⧉ where each lattice point is a cluster of 29 atoms; 1 type X, 4 type A, 12 type D_2 and 12 type D_1. The X atoms occupy the largest volume and the D_2 the smallest. Interatomic distances of neighboring atoms are as follows:

X atoms have 12 D_2 at 2.71
4 A at 2.82

A atoms have 1 X at 2.82
3 D_1 at 2.49 and 3 at 2.96
3 D_2 at 2.69 and 3 at 2.89

D_2 atoms have 1 X at 2.71
2 A at 2.69 and 1 at 2.89
1 D_2 at 2.24 and 2 at 2.38
1 D_1 at 2.45, 2 at 2.51 and 2 at 2.66

D_1 atoms have 1 A at 2.49 and 1 at 2.96
1 D_2 at 2.45, 2 at 2.51 and 2 at 2.66
6 D_1 at 2.67

(c) Complicated structure with 20 atoms of two kinds in unit cell.

Each atom of the first kind has
3 neighbors at 2.365
3 " " 2.530
3 " " 2.671
3 " " 2.675

Each atom of the second kind has
2 neighbors at 2.530
2 " " 2.615
4 " " 2.659
2 " " 2.671
2 " " 2.675

(d) Atoms arranged in pairs so that each one has one close neighbor at 2.70. Data from A.S.M. Metals Handbook.

mination of this stress, which is standardized to some extent, still seems to be subject to argument. To simplify the procedure, and to eliminate some of the difficulties encountered, the yield stress might be determined by obtaining the stress for a certain elongation of the gage length while the specimen was *still under load*, rather than determining a certain percentage of permanent set.

There is little true impact testing done today. The Charpy and Izod tests, made on notched bars, are tests of the notch toughness or notch sensitivity. The recently developed high speed impact test has not as yet completely demonstrated its usefulness and the whole subject of impact testing and the interpretation of the results is in such a confused state that it is difficult to see in what direction the next steps will be taken. That there is need for some rational method of testing which will give concordant and reproducible results is unquestioned, and until there is a greater agreement on the validity of our present tests they should be used with care and discrimination.

Modern industrial operations, with their higher speeds, temperatures and pressures, have necessitated the study of materials to indicate their behavior when subjected to these newer conditions; for this purpose fatigue, creep and wear testing have all received due attention.

These tests are all very time consuming. Recently some high speed fatigue testing machines have been developed so that a determination of an endurance limit now requires only 10 to 20% of the former time. Speeds up to 30,000 r.p.m. are possible but above 10,000 the velocity affects the results. One drawback of the fatigue test is the small, carefully machined specimen. Since slight surface imperfections greatly influence the results, the utmost care must be exercised when the endurance limit obtained from these polished specimens is to be used by the engineer in designing large, relatively rough machine parts.

Creep testing requires an extraordinary amount of time and very carefully controlled apparatus, since creep characteristics are determined for a period of 10,000 hr., during which the temperature must be maintained as nearly constant as possible and the elongation read with a high degree of precision.

Wear testing has only recently received much attention except in the bearing metal field, and there is no standard procedure. Wear is so complicated by other things such as lubrication, pressures, corrosion, and abrasive scruff, that it is possible no single wear test will be sufficient.

In the near future more work must be done on materials under vibratory conditions, on wear, and in the study of impact. Much also has still to be done toward a better correlation between the metallographic and the physical characteristics of metals.

Hardness Testing

By S. R. Williams
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THE MINERALOGIST still uses Mohs' series of minerals which will successively scratch each other as a measure of hardness. Eventually this method will certainly pass into disuse, except as a method for rough-and-ready distinctions in the field. Scratch methods have been so greatly improved in recent years that, more and more, mineralogists will be using instruments with standard size and shape of scratch point and with predetermined pressure on the scratching point. The century-old method of Mohs does not offer this advantage.

As a research tool the microcharacter devised by Bierbaum offers decided advantages. It might be classified as a scratch instrument, but when properly used the trace made by the standard diamond point should be a distinct *cut*. The width of cut for a fixed load serves as a measure of hardness. In the Graton instrument the load necessary to give a fixed width of cut is taken as a measure of hardness.

Metallurgists are responsible for the development of a number of widely used hardness testers. One may start the list with the old standby of static indentation methods — the Brinell machine. In this method, as is known to all, the diameter of indentation made by a spherical indenter under a fixed load is taken as a measure of hardness of the metal under test. The Vickers instrument uses a diamond pyramid indenter and takes the length of the diagonal of the square impression as the hardness number. Otherwise it uses the principle of the Brinell machine. In

manufacturing establishments, where quantity production is in force, the Rockwell hardness tester is unquestionably the leading instrument today. This tester uses depth of indentation made by a spherical indenter for measuring hardness.

Another widely used instrument for measuring the suitability of materials for a specific purpose is the Shore scleroscope. This is a rebound instrument in which the height to which a diamond pointed steel rod will bounce is taken as an indication of the hardness of the material on which the "hammer" strikes. For metals this device gives a great deal of information, but for other substances, notably the plastics, height of rebound is not a criterion by which to judge the hardness.

Let us not forget the file as a hardness testing instrument, ancient but nevertheless unique in its ability to explore the entire surface of a metallic part. In nearly all cases it is used for "go" and "no-go" inspection, although the art of the heat treater has now given us files of definitely graded hardness.

In the hands of its inventor, the Herbert pendulum hardness tester has advanced our ideas regarding hardness and its measurements. Not only does it offer a means for measuring hardness but also gives a measure of the degree to which a metal may be cold worked. There are other uses to which this instrument may be applied, making it the most versatile of all hardness testers. However, the Herbert pendulum and the microcharacter are distinctly research tools. On the other hand the Brinell, Rockwell and Shore instruments are for routine, quantity testing and control of uniform quality.

While not impressive, a large amount of literature is accumulating in which electric and magnetic methods are being used for measuring mechanical hardness, because variations in "hardness" do affect the electric and magnetic properties of materials.

The number of instruments for measuring hardness (suitability) runs into the hundreds. They are direct copies or modifications of those outlined above, and range all the way from portable devices to huge motor driven machines.

It may be noted that in a few lines above the word hardness was put in quotation marks. To the physicist, as well as to the inquiring metallurgist, the word has meaning only as defined by other properties. In other words, the "hardness" testers we use today — certainly the indentation machines — are based on the elastic properties, the "elastic limit" or plastic properties, of a considerable aggregate of metallic crystals. It would seem to the writer that what is needed in this field is to see if some logical relation between elastic properties and that of hardness may not be established, or, perhaps still better, hunt for some other property than hardness which would qualify as a better criterion of suitability of materials for a given purpose.

Recently, the methods of quantum mechanics have been applied to physics and have thrown much light on many of the properties of metals. Even though it may be questioned as to whether hardness is a physical property of matter or not, at any rate through quantum mechanics we are learning much about interatomic and intermolecular forces, those factors on which depth, diameter, or width of indentation of hardness testers depend.

Metallography

By Joseph R. Vilella
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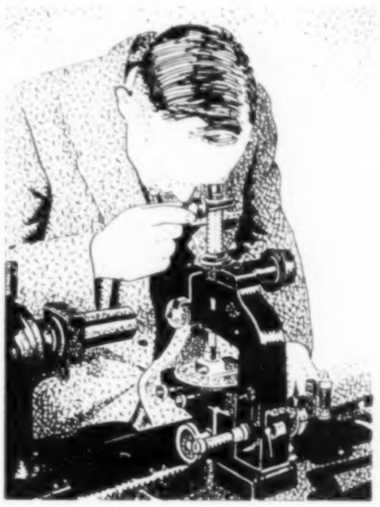
IT IS APPARENT to those who follow with interest the course of microscopy as applied to the study of metals that the minimum standard of quality which constitutes acceptable microscopic work is higher today than ever before. While the progress has not been spectacular, it has been widespread and somewhat faster than in previous years. Much of the credit belongs to the editors of technical publications for their more exacting requirements as to the quality of photomicrographs; to the local chapters of for the sponsorship of numerous lectures and educational courses on these subjects, and to the manufacturers of microscopes for the truly splendid instruments they have placed at the service of the metal industries.

The modern metallurgical microscope differs from the earlier models in two important respects. First and foremost, it is designed to facilitate the examination of metallic specimens at high power. Second, it is generally equipped for use with darkfield and polarized light illumination. As a result of the comparatively greater ease with which the structure can be examined at high power, the use of magnifications in excess of 500 diameters, which several years ago was the special province of a few experts, is rapidly becoming routine practice in many laboratories. As the metallurgist has delved into the finer details of the structure he has become

more conscious of the different configurations of structures which today are designated by the same name, and this has resulted in a strong movement for revising the nomenclature in a manner which will bring the connotations of the words abreast of present day knowledge.

The application of darkfield illumination and reflected polarized light to metallographic specimens has not as yet contributed notably to metallurgical knowledge, but they have aroused great interest among metallographers and it can be safely predicted that information of great value will appear as the metallurgist learns the use of these new tools.



A comparison of the microscopic work of 10 or 15 years ago with that of today, as reflected in the published photomicrographs, indicates that the importance of correct polishing and etching is being more generally appreciated. However, further improvement is necessary before we can make full use of the resolving power of modern objectives.

Of the metallography of steel in general it may be said that the trend is to think less in terms of equilibrium conditions and more in terms of the relationship of the structure to the transformation temperature and to the rate of transformation. Thus, such factors of steel quality as grain size and hardenability, which have no place in the equilibrium diagrams, are still being intensively studied.

Spectrography

By Thomas A. Wright
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WORKERS attending the sessions on Spectrography held by the American Society for Testing Materials and Massachusetts Institute of Technology are showing a tendency to become more critical of each others' work. This indicates on the one hand an increasing number of experienced men and of experiences, and on the other a somewhat paradoxical situation but a healthy one: Some have attained a confidence in their own method borne of repetitive experience, while others are questioning claims that do not stand up under close checking.

This condition lends proof of the steady growth of the four types of analysis furnished by this instrumental technique. In the usual order of increasing complexity these are *(a)* the simple qualitative analysis, *(b)* the study of compositional differences between samples related — or so suspected, *(c)* "go" and "no-go" inspection, *(d)* strictly quantitative analysis.

A.S.T.M. Committee E-2 activities are primarily directed to the third and fourth types and to the study of metals and alloys almost exclusively. The M.I.T. papers are more catholic in the types of substances and problems studied, although the discussion appears to concentrate on methods of excitation and measurement with problems of registration and interpretation given secondary attention. To date the A.S.T.M. has confined itself to emission spectrography (as is the immediate purpose in this present note) while at M.I.T. absorption spectrography, fluorescence and kindred phenomena have been discussed.

Furthermore, at the last two conferences at Boston, instrumentation has occupied an increasingly important position. The respective merits of prism vs. grating were debated at length, and, as to the latter, the various forms of mounting. The last word in design of either has not yet been achieved, to put it mildly.

There is now much less tendency to consider the grating as a purely academic instrument hidden away in the murky confines of a basement below some marble pillars, and the grating spectrograph is being adapted to industrial use by such means as a compact enclosure of suitable design. This will permit the analyst to extend his measurements of spectral length and intensities in the range above 7000 and up to even 12,000 Å, as well as conferring the boon of uniform dispersion over the entire range (at some sacrifice at the ultra-violet end, where the prism gives the wider dispersion). Most work, of course, is carried out in any event in the 2500 to 4500 Å range.

Men in the metal group still lead in active interest, followed closely by the biologists. However, installations in the heavy chemical field — for instance, for alkalies — are stepping up fast. Work on organic chemicals will proba-

Exposure Chart for Radiography of Steel

By Herbert R. Isenburger

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THESE DIAGRAMS for estimating the correct exposure time for the industrial radiography of steel are intended to supersede those published in **Transactions** ⊕, Vol. 23, p. 614, 1935, and are based on the following combination: Pulsating direct current tension generating equipment; line focus, grid action X-ray tube; high speed industrial intensifying screens; blue base safety film; 5 min. development at 65° F.; film density 0.7.

As an example for the correct use of charts and table, a solution is shown of this problem: "Find the correct exposure on 17-in. film at 36-in. focus-film distance for 3-in. boiler plate of density 7.85 using 220,000 volts and 8 milliamperes."

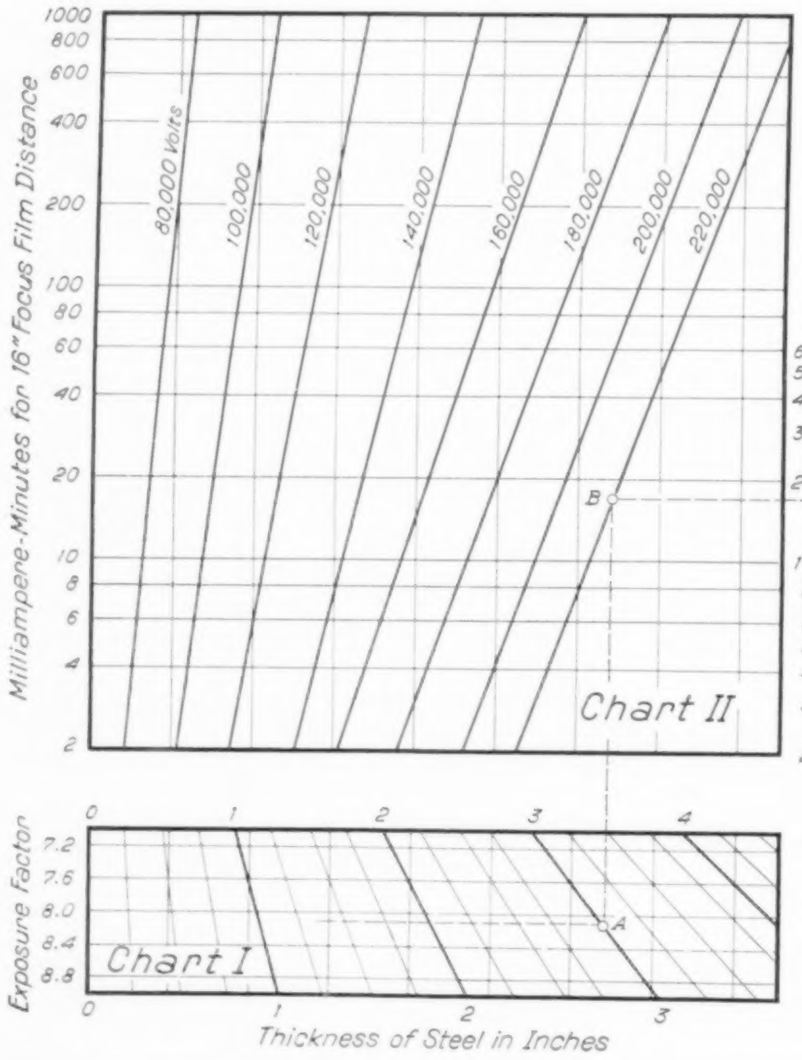
To compute the exposure factor at the ends of films of various lengths and at different focus-film distances, the factors shown in the table are multiplied by the actual density of the steel. In this example the factor 1.027 is located in the column for 36-in. focus-film in the line for 17-in. film. Multiply 1.027 by 7.85, the density of the steel to be radiographed, and the exposure factor is 8.1.

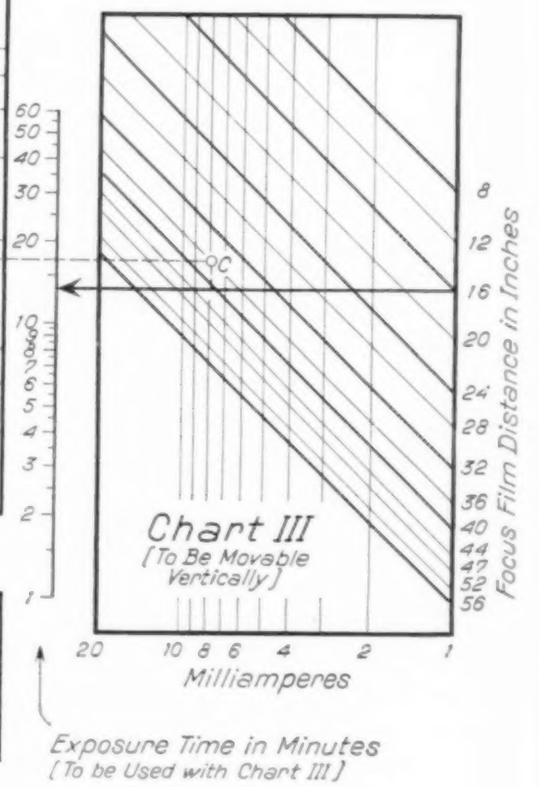
Find intersection of 8.1 with 3-in. line on Chart I (Point A), project upward to voltage of tube (Point B on 220,000-volt line in Chart II). Adjust Chart III so that Point C (corresponding to 36-in. focus-film distance and 8 milliamperes) is opposite Point B, and exposure time is read on central scale against arrow: 13½ min.

This time may be contrasted with 1 min. for the same thickness of steel of 7.6 density at 220,000 volts and 8 milliamperes but only 16-in. focus-film distance and 8-in. film.

Table of Exposure Factors

Length of Film	Focus Film Distance				
	12 in.	24 in.	28 in.	36 in.	48 in.
6 in.	1.031	1.008	1.006	1.003	1.000
8	—	1.014	1.010	1.006	1.000
10	—	1.022	1.016	1.009	1.000
11	—	1.028	1.019	1.011	1.000
12	—	1.031	1.023	1.014	1.004
14	—	—	1.031	1.019	1.006
17	—	—	—	1.027	1.011
24	—	—	—	—	1.025





bly be very extensive, if present indications keep up, as a means of controlling corrosion and choosing suitable manufacturing equipment. In fact, the spectrograph has done much to emphasize that metals introduced inadvertently can be just as efficient catalysts of chemical reactivity (sometimes unwantedly so) as if the same metals were introduced by design!

One or two disappointing installations prove the general feeling that while the new tool is obviously one for the analytical laboratory, it requires the close cooperation of a physicist for its proper working. This point is not properly recognized and bears continued repetition. It might also be mentioned that most of the special methods published have good points or even superior ones — *for particular occasions.* One has an advantage in this application, another in that. The writer sometimes feels that spectrography is headed for just as many highways and byways as analytical chemistry in its older and more familiar aspects. Why not? When spectrography is the better method, whether because of increased speed, greater precision, or lessened cost, use it.

Curiously enough there is a serious complaint abroad about spectrography. It appears that when (after proper thought and preparation) an instrument has been installed in a routine laboratory, it isn't long before the engineering or research staff pester and annoy the routine laboratory for special work — and vice-versa. The complaint is serious only for the agency that supplies the wherewithal; it means they must buy another one to keep the research group from the throats of the control crowd — and vice versa.

Radiography

By Kent R. Van Horn
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IN 1936 the American Society for Testing Materials sponsored a symposium on radiography and X-ray diffraction methods which resulted in the publication of an authoritative volume on the subjects. The discussions associated with the arrangement of the symposium suggested a need for organized research and standardization work, and a new A.S.T.M. committee designated as E-7 on radiographic testing was formally organized early in 1938. Its general scope is indicated by the subcommittee assignments: On radiography of cast metal; on technical research; on radiography of welds and weldments; on correlated abstracts; on safety; on programs. For the first time a complete session of the program at the last annual meeting of the American Society for Testing Materials was devoted to this new subject of radiography.

One of the outstanding developments in radiography was the introduction of the non-screen or no-screen film during the latter part of 1937. The chemical nature of the emulsions on the standard safety X-ray film was altered to be especially sensitive only to primary bombardment with X-rays, whereas the old standard emulsion is sensitive also to fluorescent light and therefore readily adaptable for use with the commercial intensifying screens. No benefit is obtained by employing the fluorescent type of intensifying screens in conjunction with the new product.

Speed of the new, non-screen film when used in paper cassettes or with lead screens is about 100% faster than that of the old standard. The new film has excellent contrast and detail, as there has been no appreciable alteration of grain size. They are used extensively for inspecting aluminum and magnesium castings, and steel sections of moderate thickness where intensifying screen technique is not generally employed. They have also been readily utilized for X-ray diffraction analysis where a 50% reduction of the exposure times (a matter of hours) has been particularly welcome to busy laboratories.

Another interesting innovation has been the high speed developer "Kodalk". This resembles the rapid commercial alkali (NaOH) photographic developers, but whereas the usual developers require 6 min. (time specified for the 1938 standard film) at 65° F. for normal development, the new product requires 3½ min. Very acceptable results are now regularly attained in industrial practice.

These two improvements, noted above, are particularly noteworthy inasmuch as there has been no unusual changes along these lines during the past five years. However, in the same period the leading manufacturer has contributed a continuous series of new developments in the materials, design and construction of X-ray tubes. The most recent is the bias feature of the self-rectifying high voltage tubes. The cathode structure is negatively biased (at approximately 1000 volts) with respect to the emitting filament, for the purpose of obtaining

better quality and quantity of radiation. The negatively biased cathode functions as a grid, or increased space charge, that makes it difficult for the current to flow at a low voltage and thereby improves the character of the radiation for the current that does flow at a given peak kilo-voltage.

In 1937 there were about 48 X-ray units distributed among 34 manufacturers of steel boilers and pressure vessels. The number represents the progress of radiography in this industry since the inception of the A.S.M.E. Boiler Code in 1931. There is no record of the failure of any vessel welded under X-ray control according to the tentative standards, and stress relieved. In 1938 eleven new X-ray units have been installed for the inspection of steel welds in this country and it is expected that this phase of radiographic testing will continue to expand at the present healthy rate.

The first three industrial X-ray equipments were installed in ferrous or non-ferrous foundries prior to 1931. However from 1931 to date, the application of radiography in the foundry has proceeded very slowly compared to the welding field as only a half dozen large producers of castings now have X-ray apparatus. Reasons for reluctance on the part of foundrymen to employ this method appears to be unfamiliarity with the test, fear of the reliability of the results, cost of equipment, and cost of operation. During 1938 there has been a renewed interest among consumers as well as the producers of castings and there were four new X-ray installations in foundries. It may be predicted there will be a large increase in the amount of radiographic testing done in the future in the foundry.

Electron Diffraction in Metallurgical Research

By Lester H. Germer
Bell Telephone Laboratories, New York

THE DISCOVERY that a beam of electrons can be diffracted by regularly arranged atoms in crystals was made over 11 years ago, and it was almost immediately realized that this phenomenon offers a new means of studying the structure of crystals. The extent to which this is being done is indicated by about 800 papers which have been published. Of these perhaps half are devoted to investigations that are of potential direct value to metallurgy, to chemistry, or to various applied sciences.

Sharp photographic patterns produced by electrons diffracted by masses of small crystals show a series of concentric circles, and from such patterns one is often able to determine the arrangements and spacings of the atoms in the crystals, in a manner analogous to the determination of crystal structure by X-rays.

Yet the fields of usefulness of X-ray diffraction and of electron diffraction do not greatly overlap. X-rays are so penetrating that with them one can investigate only great aggregates of atoms. Electrons, on the other hand, have such slight penetrating powers that they give information regarding the arrangement of atoms in very thin films or in very thin surface layers, on the order of 10 to 20 molecules thick. In a number of cases investigators have even determined successfully by means of electron diffraction just how molecules are arranged in *one single layer* upon a supporting surface.

Such extremely thin films cannot be studied by X-rays. Surface phenomena, which are appropriately studied by electron diffraction, are much less thoroughly understood than are volume phenomena. It is, however, not at all clear that the latter are more generally important than the former — perhaps not even to metallurgists.

Electron diffraction surface studies which are immediately related to metallurgy include investigations of corrosion, crystalline orientation in thin layers of electrodeposited, vaporized and sputtered metals, and diffusion of one metal into another near their interface. It must be admitted that these researches are rather scattered and haphazard, and have not yet proven of indispensable value to metallurgists. The reason for this state of affairs is not hard to find, for investigations have been carried out mostly by physicists and chemists who have little interest in metallurgy and only slight acquaintance with its needs.

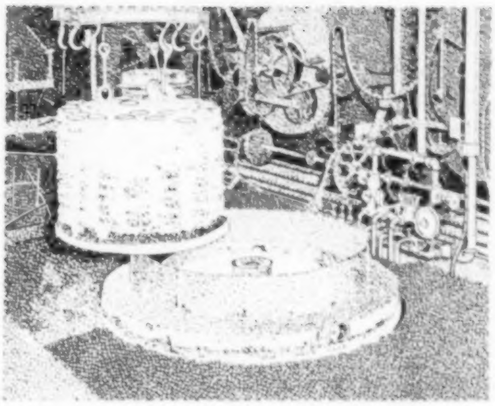
Perhaps the structure of thin films, although of great metallurgical importance, lies just over the ill-defined border between metallurgy and chemistry. The chemists have certainly shown great zeal in the use of electron diffraction, but they have applied it mainly to problems which are most important to them — determinations of the arrangements of atoms within molecules. A number of these, described in about 100 published papers, have been strikingly successful. It seems altogether likely that ultimately the potentialities of electron diffraction in the field of metallurgy will be equally well exploited.

HEAT TREATING

METAL PROGRESS

OCTOBER 1938

Heat Treating



Austenite Transformation

By Edgar C. Bain
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Pittsburgh, Pa.

THE LAST FEW YEARS have witnessed a great clarification of the central problem of steel treatment — that is, the atomic mechanisms by which the same steel may be made soft and formable or, when desired, exceedingly hard (and yet not too brittle). By heat treatment alone, suitable steels can be induced to acquire a wide variety of properties not exceeded in range by any metals. These properties are the direct result of structure, and this microscopic architecture is easily controlled by the heating and cooling of the steel.

Before the research of Portevin in 1919 pointed out the error, it was supposed that the heated steel (that is, austenite) began at once to change its structure the moment it was cooled below a certain "critical" temperature. By quenching, it was supposed, one arrested the transformation as desired. Portevin showed that it was the austenitic condition itself which was preserved down to lower temperatures and that at this lower temperature only did the austenite change to the hard constituent martensite which, in turn, developed the superior microstructures on reheating.

In 1930 Davenport and Bain elucidated the transformation still further by undercooling austenite quickly to numerous temperatures, holding at those temperatures for increasing times, thus determining the transformation *rates* at constant temperatures covering the range from A_1 to room temperature. They found that there were two modes of transformation: First, to the lamellar distribution of carbide and ferrite which occurred by nodular growth and second, by intermittent acicular transformation on crystallographic planes, which did not yield lamellar carbide. For carbon steels there were two temperature ranges of rapid reaction, one at about 1000° F. and the other near room temperature, producing respectively fine pearlite and hard martensite. At intermediate temperatures the austenite transformed, when maintained sufficiently long, to an acicular product later named "bainite", softer than martensite and having properties superior to martensite tempered to corresponding hardness.

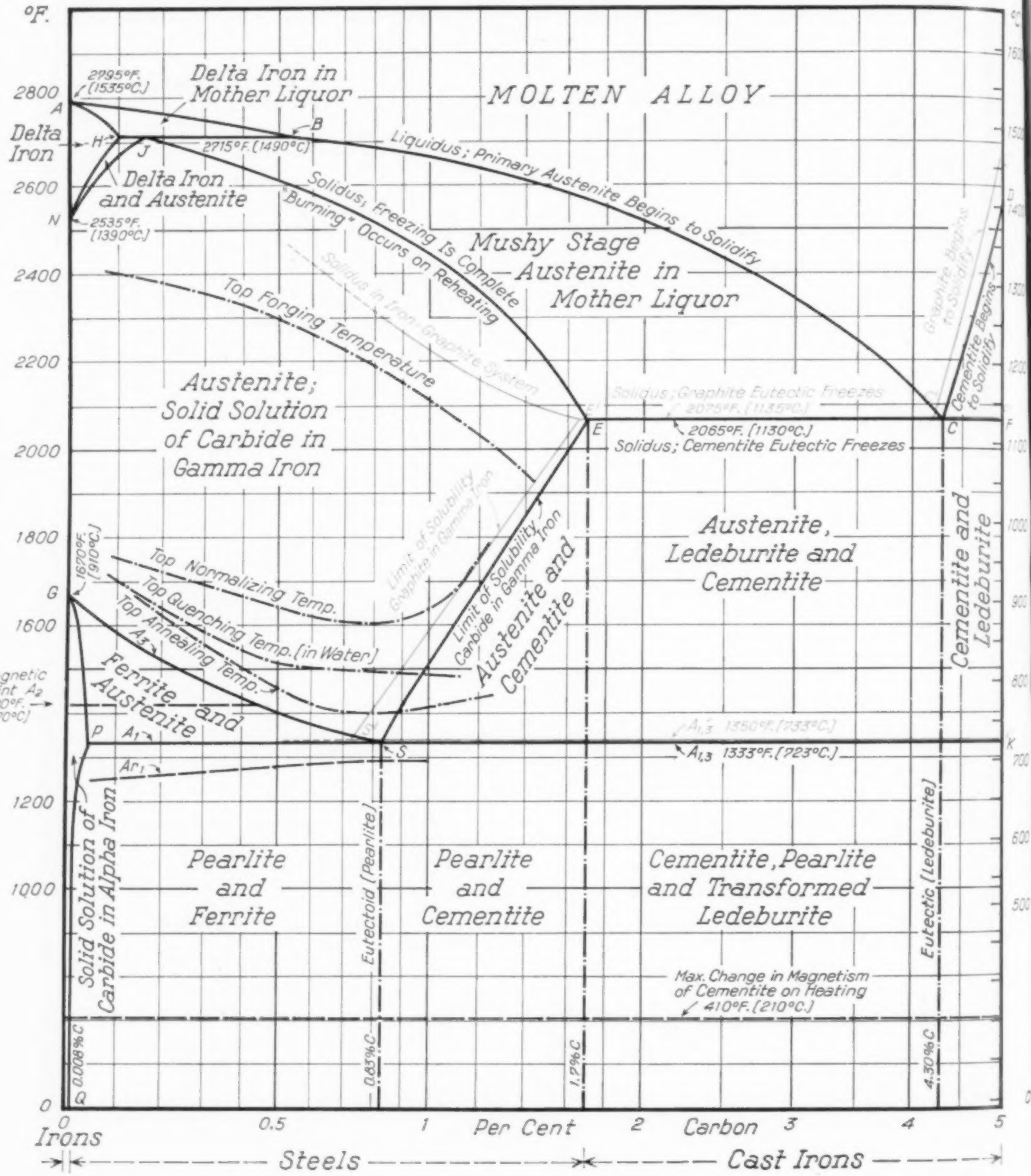
The real function of quenching (to avoid transformation of austenite to fine pearlite) and the dependence of structure and properties upon temperature of transformation rather than upon cooling rate *per se*, were thus well established. Further study showed how the "hardenability" of a steel is a function of its transformation rate above the upper temperature of maximum transformation rate, and that this significant rate of reaction is retarded by alloying elements dissolved in austenite, and accelerated by fine austenite grains. Fineness of austenitic grain at high temperature is maintained either by undissolved carbide particles of special alloying elements such as titanium, vanadium, molybdenum or tungsten, or by dispersed particles containing alumina.

This constitutes something of a philosophy of heat treating carbon and alloy steels.

More recently the transformation rate patterns, the so-called "S-curves", have been developed for a number of alloy steels. It became apparent therefrom that certain elements, such as chromium or molybdenum, exert an influence to distort these rate curves to longer intervals of time at the higher ranges of temperature, thereby not only contributing hardenability but providing the possibility of securing the preferred "bainite" type of structure even when the steel is simply cooled at a moderate rate in a medium at room temperature.

Iron, Iron Carbide Equilibrium Diagram

Approximate Iron-Graphite Diagram in Green



Except as noted hereafter, lines are reproduced by courtesy of The Engineering Foundation from diagrams published in one of the Alloys of Iron Monographs: "Alloys of Iron and Carbon," Vol. I on Constitution, by Samuel Epstein.

Delta iron region and solidus by Frank Adcock, *Journal* of the Iron and Steel Institute, 1937-I.

Forging and heat treating temperatures from Recommended Practices, 1936 Metals Handbook.

Solidus in Iron-Graphite System according to Kaya, Honda and Endo, *Science Reports*, Tohoku Imperial University, 1925 and 1927.

Ar_1 according to Hoyt and Dowdell, "Metals and Common Alloys," for cooling rates of 1° C. in 3 sec.

Line GPQ according to J. H. Whiteley, *Journal*, Iron and Steel Institute, 1936.

Solidus in graphite system left of E′ as suggested by Harry A. Schwartz.

Great progress is now being made in developing the laws of hardenability. The connection between transformation rate and hardenability is becoming clearer and both are being related to nucleation rate in the transformation of austenite. Nucleation is found to be itself far less of a mystery and more of a measurable phenomenon than had been generally supposed. Papers on these subjects at the 1938 National Metal Congress mark another rapid advance in the quantitative concepts of hardenability.

Crystallographic Problems in the Heat Treatment of Steel

By Robert F. Mehl
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Head, Department of Metallurgy,
Carnegie Institute of Technology

THE subject suggested by the editor ("Crystallographic Problems") was so large and the space assigned (one page or less) was so small that it appeared best to limit it to the heat treatment of steel, as in the sub-head above. A secondary advantage is that the reader can get a fuller argument and literature references from the paper on "The Physics of Hardenability" prepared for the forthcoming convention.

The lattice structures of austenite, of ferrite, and of cementite are now well known. The formation of pearlite from austenite presents no problems so far as the lattices of the constituents are concerned, but the mechanism by which pearlite forms, and the mechanism by which the other decomposition products of austenite form, present a number of basic problems awaiting solution.

It has been amply demonstrated that pearlite forms by a process of nucleation and growth, but the structure of pearlite as seen in the microscope offers no evidence as to whether the initial nucleus is ferrite or cementite. Determination of the orientation of ferrite in pearlite with respect to the parent austenite by Mehl and Smith has disclosed a relationship quite different from that which occurs when ferrite is known to form directly from austenite, as in hypo-eutectoid steel. It seems not too speculative to assume, therefore, that cementite and not ferrite nucleates the formation of pearlite.

As pearlite forms isothermally at lower and lower temperatures, it becomes finer and finer in structure, and finally, at about 275° F. below Ae_1 it no longer forms, but is replaced by a type of structure having a somewhat feathery aspect under the microscope, and which has been called "bainite". This appears to form by a process of nucleation and growth. Pearlite evidently ceases to form at lower temperatures because the stable cementite nucleus at such temperatures would be sub-molecular in size. If, however, bainite were nucleated by ferrite, which possesses a smaller unit lattice cell, it could form at a lower temperature, and if a determination of the orientation of ferrite in bainite with respect to that of austenite showed the relationship to be that characteristic of the formation of ferrite directly from austenite, differing fundamentally in this way from pearlite, we could fairly conclude that bainite is an aggregate of ferrite and cementite nucleated by ferrite.

The formation of true martensite at temperatures of 400° F. and lower is now a well-understood process. The discovery by Fink and Campbell that drastically quenched martensitic steel contains a tetragonal lattice was explained in discussion by Bain as a result of an incomplete alteration of a face-centered lattice to a body-centered lattice, and later and more fully by Kurdjumow and Sachs as a result of an incomplete process of the shearing upon the octahedral planes of the austenite which when complete changes the austenite lattice to the ferrite lattice. This process of shear, which appears to be the process common to the formation of all Widmanstätten figures, is quite similar to that which occurs in twinning, with each "needle" (in reality a plate) traversing the whole grain with extreme rapidity — on the order of 0.02 sec. On tempering, this tetragonal, white martensite decomposes to a dark "martensite" in which the tetragonal lattice has decomposed to ordinary ferrite with the rejection of cementite.

It has ordinarily been assumed that the martensite plate lies parallel to the octahedral plane of austenite; Greninger, however, recently reported that the martensite plate in hyper-eutectoid steels lies parallel to the (421) plane in austenite, the plane along which pro-eutectoid cementite forms. This is difficult to reconcile with the work of Kurdjumow and Sachs and the point requires further study, for it is of basic importance to an understanding of the mechanism of the formation of martensite. It is possible that Greninger's sample contained pro-eutectoid cementite and that the martensite formed upon this pseudomorphically. He and other workers observed also that the residual

austenite is little distorted. This surely requires explanation in view of the volume changes which accompany the formation of martensite.

In passing it might well be noted that the development of an X-ray diffraction method for the determination of the percentage of residual austenite in martensite would be of considerable use in the study of heat treatment. At present other methods, particularly the magnetic, are more satisfactory.

But what is the product of decomposition between the temperature at which bainite ceases to form and ordinary martensite forms? It is dark and acicular in structure; it has an appearance very similar to that of tempered martensite; it forms very likely not by a nucleation and growth process but by a shearing process. If a determination of the orientation relationships between the ferrite in this structure and the austenite from which it forms should show a relationship identical with that in tempered martensite, and if, further, the sonic and electrical methods employed by Förster and Scheil should show the process to proceed in a similar spasmodic fashion with high speed, we could confidently conclude that this structure differs from martensite *only* in the circumstance that the tetragonal lattice decomposes as it forms, and we could rest at least momentarily content that the chief questions concerning the mechanism of decomposition of austenite and of the nature of the reaction products are answered.

Precipitation Hardening

By E. H. Dix, Jr.
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New Kensington, Pa.

OUR KNOWLEDGE of the precipitation hardening of metals can truly be said to date back to the discovery by Wilm of the heat treatable aluminum alloy "duralumin." It remained for Merica, Waltenberg and Scott to propose what is today often referred to as the "simple" theory of precipitation hardening. At the time that it was proposed, however, the theory seemed far from simple and was a very bold departure from conventional metallurgical thinking. Archer and Jeffries, by their conception of slip interference as the mechanism of hardening, strengthened the plausibility of the "simple" theory.

Merica, in his 1932 Institute of Metals lecture on the Age Hardening of Metals, admirably summarized the state of our knowledge at that time. The information then available led him to conclude that his simple precipitation theory required modification to account for the aging of duralumin at room temperature. His "knot" theory proposed at that time is only one of many dealing with the "pre-precipitation" phenomena. Among others who have concerned themselves with speculation on plausible structural rearrangements prior to precipitation should be mentioned Fränkel (although he suggested a chemical change), Gayler and Preston, Masing, and Dean.

Apparent anomalies in electrical resistivity measurements, volume changes and incubation periods have all been cited against "simple" precipitation but none of the pre-precipitation theories seem to offer a more rigorous explanation. Merica apparently was led to modify his original theory largely because of the X-ray data presented by E. Schmidt and Wassermann, and by M. Göler and Sachs. At that time, the X-ray seemed the most sensitive tool for determining evidence of precipitation, and if no such evidence could be detected in the early stages of room temperature aging, then it seemed a fair conclusion that precipitation was absent.

More recently Fink and Smith have presented evidence which seems to indicate that the best X-ray technique is incapable of showing precipitation in as early a stage as can now be seen microscopically. (Improvements in metallographic technique contributed by F. Keller made this possible.) Although this evidence has not yet received general acceptance, it has put the burden of proof on the opponents of the simple precipitation theory.

Among collateral facts of importance may be mentioned the discovery by Wassermann and Werts of an intermediate transition form of the precipitate $CuAl_2$. Likewise, Mehl has shown that the precipitation in the aluminum-magnesium silicide system is not in the crystal form of magnesium silicide precipitated at higher temperatures. Cohen, working with silver-copper alloys, introduced the conception of double aging peaks. Fink and Smith have shown that in aluminum-copper alloys these double aging peaks can be explained on the basis of selective precipitation occurring at different rates in different parts of the structure.

The total effect of aging may be the aggregate of several processes of precipitation occurring simultaneously. If to this is added the recognition that coalescence is taking place con-

currently with precipitation, then the simple precipitation theory seems to fit known facts as well as the more speculative theories involving some sort of atomic rearrangement prior to actual precipitation. That the theoretical explanations are of importance is proven by the fact that precipitation hardening, far from being a phenomenon unique to an aluminum alloy, is a general action occurring in hundreds of useful alloys, including plain carbon steel.

Heat Transfer

By Floyd E. Harris
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General Motors Corp., Flint, Mich.

THE PROBLEM involved in all heat treating processes is uniformity of heating at a commercially high rate. To cover specific cases, the factors involved may be stated broadly:

1. Diffusivity of material being heated, its effective mass, and the loading factor.

2. Mechanism of heat transfer, whether radiation, convection, or induction.

3. Cycles in heating process from the cold to the point of temperature attainment.

The diffusivity of steel is so high that, with moderate sections and with the comparatively low temperatures usually employed in heat treatment, the rate of heat absorption is faster than the rate of heat transfer to the metal surfaces. This avoids hot spots in the metal being heated. In mass loads of small sections, however, the diffusion of heat is a more important problem than the uniform heating of a single piece.

Convection transfer coefficients, with low head temperatures, compare favorably with transfer by radiation at low temperatures. At elevated temperatures, on the other hand, transfer by radiation far exceeds that possible by convection. Hence the circulation of heated gases at low temperatures, say under 1100° F., through closely packed loads of small section, gives fast and uniform heating. The low transfer coefficient, even with high velocities, is offset by the fact that the heat content of the charge at low temperature is low, which means that temperature is attained relatively rapidly.

High temperature processes involve greater heat inputs, naturally, but transfer by radiation increases much faster with the temperature increase than does the heat content of the part being heated. In fact the time required to heat small sections by straight radiation from 100° F. to 1500° F. with a head temperature of 1500° F. is barely one-half that required to heat the same section from 100° F. to 1000° F. with a head temperature of 1000° F. However, surfaces shielded from the radiating source by dense loading cut down the effective exposed area so that a dense load will give the same effect, as far as heat transfer by radiation is concerned, as if the entire charge were one single piece of greatly increased cross section. Radiation is much more effective, then, with light loads and at high temperatures, while the total transfer by convection is more effective with heavy charges (due to the greater surface areas exposed) and is not lessened appreciably by low temperatures.

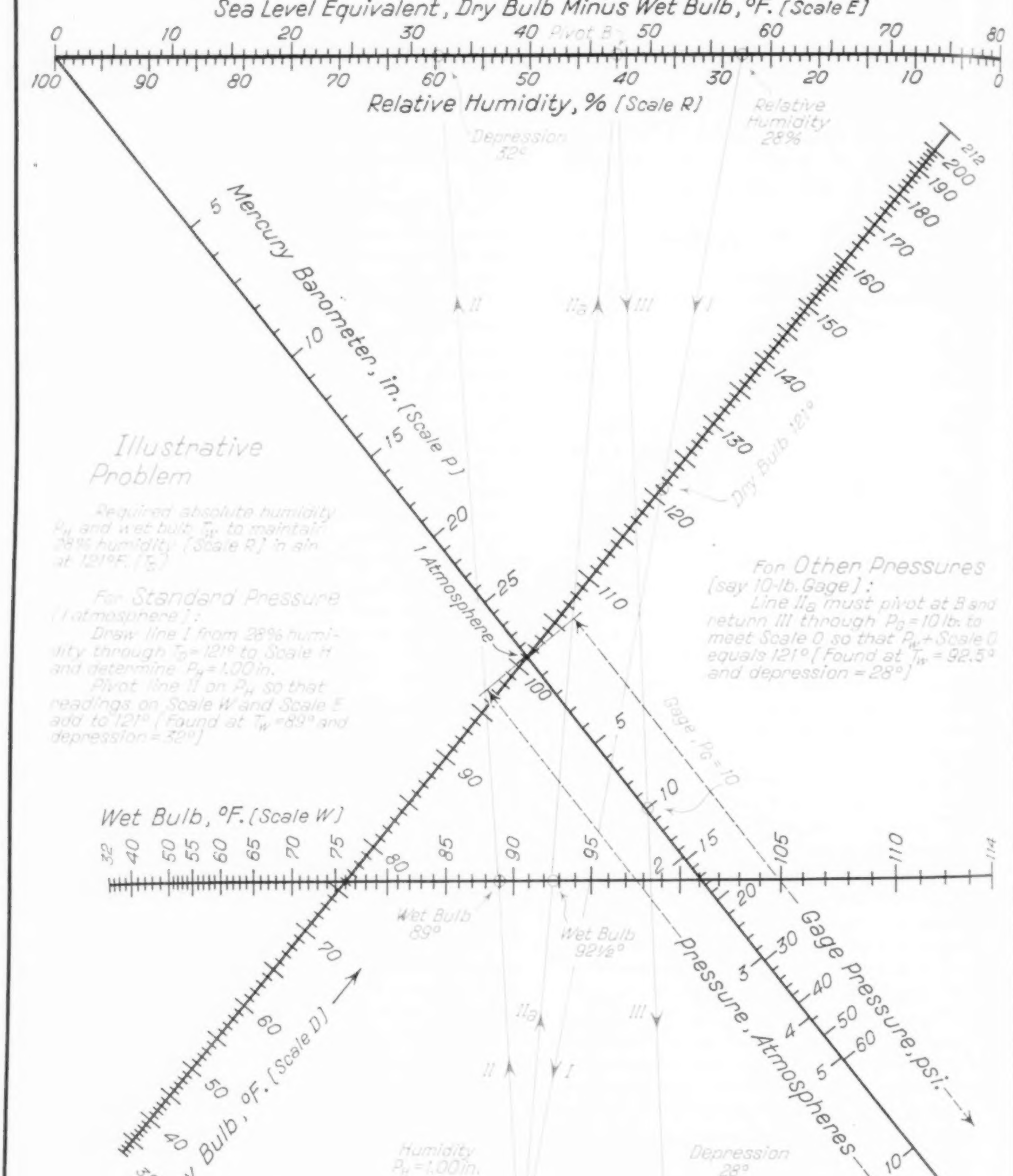
This analysis of a heating cycle shows high heat absorption and high transfer when the temperature differential is great, whereas when the charge approaches closely the desired temperature the heat absorbed by the charge gradually decreases until heat transfer is nil (the charge being thoroughly at temperature). It also suggests the employment of radiating surfaces at the beginning of the heating cycle to take care of the high heat release where heat absorption can be great, and the use of recirculating gases as the material approaches heat.

A continuous furnace employing this method gave close control and halved the time required for the same operation in a straight radiation unit. Here, in a continuous fuel fired unit, over 80% of the total heat input required is released in the first one-third of the furnace, with no attempt at circulation of gases through the stock. Products of combustion emerging from the end of this relatively short zone are recirculated through the remainder of the furnace. Close control of work emerging at moderate temperature is accomplished with a one-point temperature control. To summarize, direct radiation is used to transfer the larger portion of the heat required at a point where overheating cannot occur, while the finishing and soaking portion of the heating operation employs high velocity gases where uniformity rather than heat input is the controlling factor.

Transfer rates accomplished by induced high frequency electric currents permit shallow surface heating on small sections, that would be otherwise possible only by employing radiating surfaces at extremely high temperature, and high temperature differentials. Where this effect is desired a control can be obtained by induction heating that would be impractical to accomplish by heat transfer through radiation or convection.

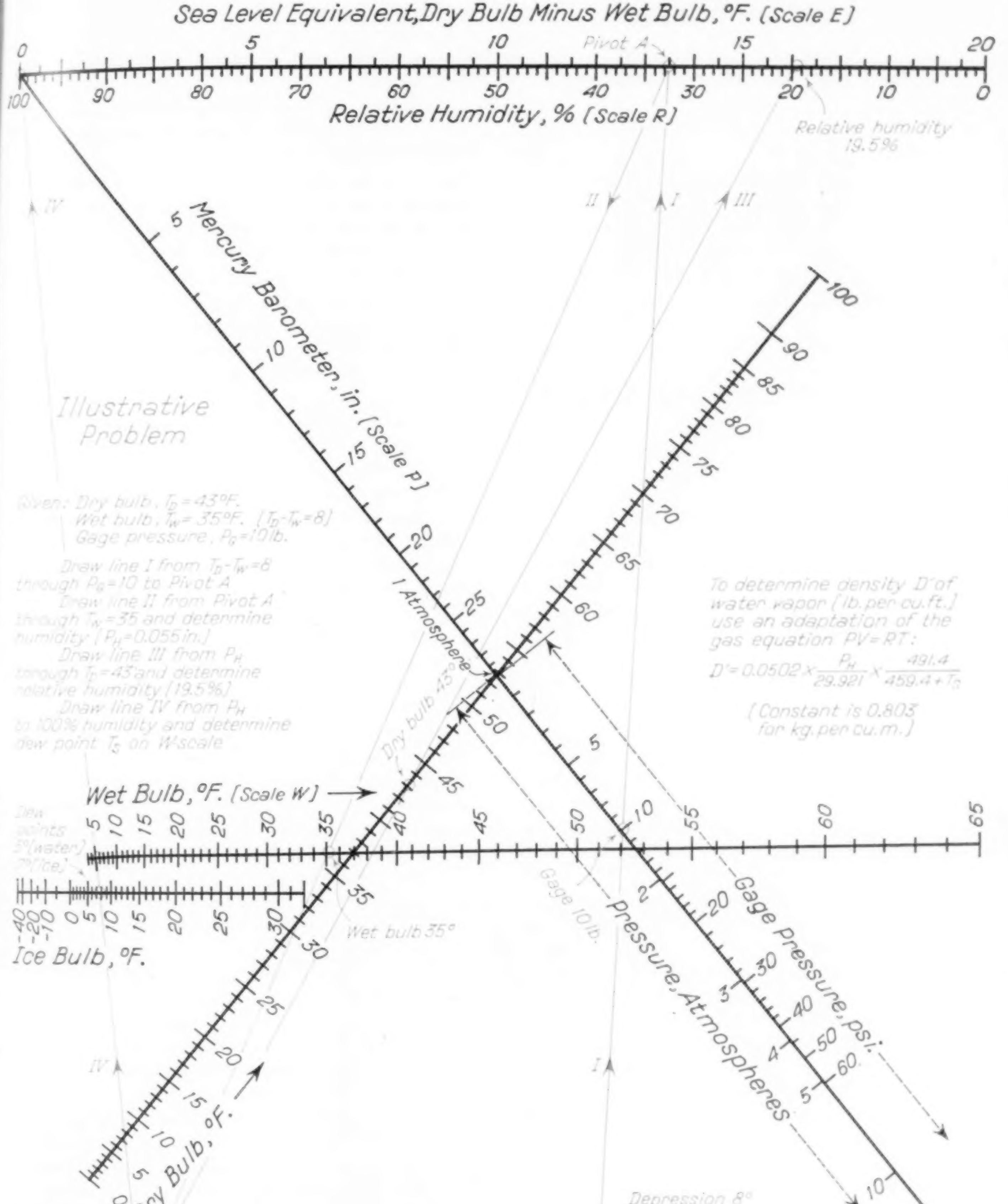
Psychrometric Chart, High Range

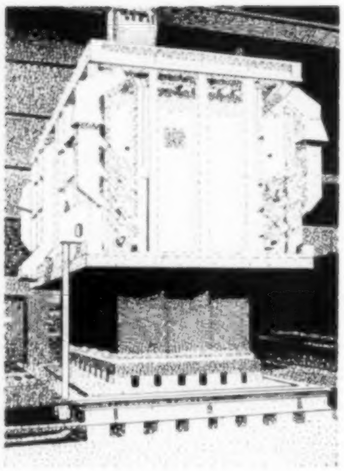
By Donald B. Brooks; National Bureau of Standards. Publication M-146



Psychrometric Chart, Low Range

By Donald B. Brooks; National Bureau of Standards. Publication M-146





Annealing Strip-Sheet

By James J. Bowden
Chief Metallurgist, Cleveland District
Republic Steel Corp.

USE OF CONTINUOUS MILLS for flat rolled products have developed intricate problems as to how the auxiliary equipment may keep step from the standpoint not only of costs, which must be lowered, but of tonnage produced, which must be increased, and quality, which must be improved.

Annealing equipment is one of the more important and, at the same time, complicated of these accessories.

At first glance, the approach to the solution to this problem of annealing would be to have it function continuously as do the mills. However, in planning, engineering and building equipment to do this, we find that, while it is highly desirable, we cannot in all cases adapt continuous annealing equipment. The reasons for this limitation are cost, tonnage and last but not least, quality.

Fundamentally, the purpose of annealing is to remove the strains left after the cold work required to reduce the hot rolled sheets or strip to the approximate finished gage and to obtain the proper grain structure and ductility. Such annealing consists of heating the steel to temperatures closely approximate to the lower critical temperature Ac_1.

(This type of annealing should not be confused with what is commonly referred to as normalizing, which involves a phase change because the temperature in the steel exceeds the Ac_3 point.)

Generally speaking, the heat treating equipment for cold rolled sheet or strip is of two classes or types:

1. The bulk or box type, which includes stationary furnaces, bell type furnaces, and Dressler type furnaces.

2. The continuous type, wherein only single thicknesses are heat treated, generally in continuous lengths.

The bulk type of annealing is very much older in point of service. Protection of the surface of the steel against oxidation was formerly a serious problem — in fact, all annealing was generally accompanied by a mass of cast iron borings, charcoal or coke placed inside the cover to prevent scaling. In this connection, however, great strides have been made so that the modern bulk type of annealing now uses a deoxidizing gas for this purpose, manufactured and dried to a specific moisture content before admitting it into the box. In this manner discoloration and oxidation of these cold rolled sheets is completely controlled. Box type annealing, when carried out on suitably hot rolled, pickled and cold rolled material, gives us a product which has a relatively fine, uniform, equiaxed grain structure, resulting in satisfactory hardness and ductility, which, of course, means good drawing quality in the customers' plants.

Continuous annealing, on the other hand, consists of passing a single thickness of the material through a long furnace, the atmosphere of which is controlled either to prevent oxidation completely or to obtain the desired type of oxide finish. This type of furnace is divided into two principal chambers, the heating zone and the cooling zone. The furnace is maintained at a temperature which will impart to the steel a heat which will be higher than Ac_1 but lower than Ac_3 (although complete normalizing may be done by increasing this steel temperature to a point above Ac_3). The length of time in the furnace will depend on the temperature maintained, the thickness of the material, and the speed at which the furnace is operated. These three variables, when taken into account with the tonnage desired, will determine just how long the furnace should be.

The product of the continuous furnace is very satisfactory for certain applications; however, the material is somewhat harder and has a higher yield point than box annealed sheets. Continuous furnaces have a fairly large range of application, but their use has been confined principally to the narrow widths (strip rather than sheet).

From the standpoint of cost and tonnage produced, the bulk type of annealing will produce more tonnage with the same floor space and do it more economically. There is some advantage, however, in the continuous type furnace from the standpoint of flexibility. The continuous type is also favored over the bulk type in the length of the annealing cycle, discontinuous annealing requiring a much longer time to heat and cool because of the larger tonnage per charge, whereas the continuous furnace cycle can be quickly v a r i e d to suit scheduling conditions.

Heat Treatment of Tools
High Speed Steel Cutters

By J. H. McCadie
Metallurgist, National Twist Drill & Tool Co.

MANUFACTURE of high speed cutting tools such as twist drills, reamers, hobs, milling cutters, broaches, taps and thread chasers, has become a very competitive, specialized business. A great many of these are single purpose tools, developed for one particular operation, and must be engineered and heat treated to give maximum production under these special conditions. It is also necessary to manufacture tools to very close dimensional tolerances, and the fineness of finish (which also includes heat treatment) will reflect the quality of workmanship employed in making the tool.

Selection of equipment to heat treat high quality tools will depend more on the size and kind of work to be hardened than on the type of high speed steel in the tool; the latter should largely depend on the skill developed in getting maximum efficiency from a particular steel.

A rough outline of the operations in heat treating high speed is as follows:

Preheat slowly and uniformly to from 1300 to 1600° F. When hardening large tools or where distortion must be held to a minimum, it is essential to preheat very slowly and uniformly. To accomplish this it is often advisable to use two preheating furnaces, one held at from 1100 to 1200° F., and the other at 1300 to 1600° F.

Transfer the preheated tool to a high heat furnace maintained at 2150° F. to 2400° F. The exact temperature depends on the hardening range of the steel and the kind and size of tools; the lower part of the range is for the molybdenum steels, and the upper part for the tungsten and tungsten-cobalt types. In order to obtain the most satisfactory results, the tool should be brought rapidly to heat in the high temperature furnace. High speed steel tools should be held or soaked at the high heat only for sufficient time to get a good solution of the carbides without an excessive grain growth.

Quench the tool in oil, air or molten salt bath. To reduce the possibility of breakage or undue distortion in intricately shaped tools, it is advisable to quench in a salt bath maintained at from 1100 to 1250° F. If a salt bath is not available, quench in oil and remove the tool from the oil while still red (approximately 1100 to 1300° F.) and cool slowly in air.

If it is necessary to do any *straightening* on the tool, it should be done at this time before it is tempered and, if possible, before it has cooled to room temperature.

Reheat uniformly to from 1025 to 1150° F. Hold or soak at this temperature for from one to four hours, the exact time and temperature depending on the hardness and toughness desired. To increase the efficiency of some tools, it is sometimes desirable to double temper; in doing this the tools should cool to room temperature between these two operations.

Controlled atmospheres were developed to satisfy a demand for more accurate dimensional change in hardening and a surface that is not injured in hardening. They are now available in both the electrical and fuel fired furnaces; in either case the atmosphere in the heating chamber is independent of the source of heat. This atmosphere may be the products of combustion, which can be freed of any or all undesirable constituents, and is a great help in reducing the hazards in hardening high speed. A gas analysis apparatus will be found to give much help in determining the best atmosphere by the trial and

error method, and then making sure that this best atmosphere is maintained.

Salt bath heating is generally done in three units — preheat, high heat, and quench — operated at the same temperatures as in the conventional methods of hardening. For tools that cannot be ground after hardening or where it is necessary to keep the surface of the tools in the best possible condition with a minimum rounding of sharp edges, this method of hardening will give excellent results. Salt baths are now available in which high speed steel can be hardened with no decarburized surface; the only change in dimensions will be that caused by the change in structure of the steel in hardening and by the stresses set up in uneven quenching.

For machining hard or abrasive materials it has been found that a thin, hard case obtained by soaking the finished and hardened tools in a molten cyanide bath at 1050° F. sometimes greatly increases their life.

Protective Atmospheres for Scale-Free Hardening

By C. E. Peck
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Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

SCALE-FREE HARDENING usually applies to the hardening heat treatment of machine parts surrounded by a protective atmosphere prior to the time the parts are quenched in a liquid. In the present state of this development the process produces work which is very clean and which is entirely free of scale. The process does not necessarily produce parts free from decarburization because the cheapest and most easily produced atmospheres of protective type are not always in equilibrium with the carbon content of the steel being hardened.

The protective type atmospheres are produced in commercially available equipment by partial combustion of hydrocarbon fuel gases, typical being the products of combustion of natural gas with six parts of air. This produces a mixture containing approximately 15% hydrogen, 10% carbon monoxide, 5% carbon dioxide, 0% oxygen, moisture content equivalent to saturation at room air conditions, remainder nitrogen. This gas will not oxidize the steel at the normal hardening temperatures (1400 to 1700° F.) and since the work is usually quenched in a liquid, no oxidation can take place during slow cooling through the range 1100 to 800° F. In other words, the gas is definitely reducing at the higher temperatures used in hardening, whereas it may be oxidizing at lower temperatures. For this reason, scale-free hardening is easier to attain than bright annealing on a slow cooling cycle, and wider variations in moisture content are permissible.

An atmosphere such as that mentioned above is generally in equilibrium with carbon content of steel up to approximately 0.50%. For higher carbon steels the gas is definitely decarburizing, even though it is non-oxidizing. In many applications the amount of decarburization is small and is not objectionable. If it is desired to prevent it entirely, the above gas must be thoroughly scrubbed of CO_2 and also dried to a dew point below −40° F.

Commercial equipments are now in actual operation and can be obtained to scrub out the CO_2 thoroughly, as well as to dry the gas thoroughly. Experience has proven that thorough drying of the gas without removing the CO_2 does not prevent nor does it decrease the rate of decarburization. Both purifications are needed.

Commercial availability of efficient equipment for removing CO_2 is a very recent development. Its use would only be necessary on those hardening applications where absolutely no decarburization can be permitted, and this prohibition is important enough economically to warrant the necessary additional investment and operating costs. Since a large amount of the possible applications of scale-free hardening are not concerned with decarburization, the use of purifying equipment will be limited.

Carburizing

By Gordon T. Williams
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Cleveland, Ohio

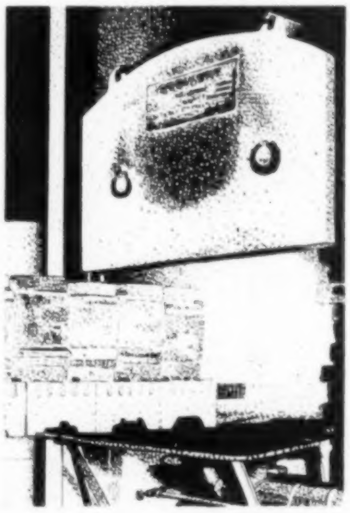
THAT CARBURIZING is on the upswing is obvious to anyone in that somewhat paradoxical position of having an ear to the ground and an eye to the future! Ten years ago there were many indications that the trend was quite the opposite, due to expense and to the higher distortion of carburized articles then necessarily endured. Today the use of carburized transmission gears in automotive practice is very widespread, sharing the field with gears quenched from cyanide or from liquid baths giving a lower nitride case. In many other fields the trend toward carburized gears is evident.

Let us consider some of the factors that

have promoted this trend to carburizing. Steel improvements have been very important indeed. Materials of predictable distortion and dependable hardening have become generally available. This, in turn, comes from modern control of grain growth tendencies. The first advantage gained from grain size control was that, in many cases, work could be quenched direct from the carburizing pot with minimum distortion. The economy of this procedure was advantageous, also. Mechanical analysis of the problem then showed that resistance to bending stresses could be given, in a carburized part, by a deep case with a soft core, or a shallower case if the core strength was increased. At the same time, grain size control had decreased the sensitivity of higher carbon materials to quenching temperature, so that the initial carbon content of steel to be carburized has been raised, the case depth being decreased at the same time, with resultant economies.

This trend culminates in the manufacture of automobile gears, which, in many plants, are made of the usual "oil hardening" steels of 0.40 carbon, but heated for hardening in a continuous furnace having an actively carburizing atmosphere to produce a case 0.006 to 0.010 in. deep. Their service life has been found to be excellent — comparable with that of similar gears heated in cyanide.

A better understanding of the carburizing process has come out of the many recent studies of gas equilibria and reactions. Essentially non-sooting but actively carburizing gas atmospheres have broadened the application of the process. Interesting reports also come of practices where ammonia is introduced either with or subsequent to gas carburizing, thus producing a superficial layer containing some intensely hard nitrides.



No very new developments seem to be worthy of note in the field of carburizing by compounds, but economies have been made by a study of container design and packing methods. Carburizing by compounds will probably never be without wide use, but it would appear that it has now reached its highest development. The specially designed, closely conforming containers required to compete with gas carburizing will not be economically feasible for a wide variety of sizes and shapes each in rather small production, but carburizing by compounds is surely the most fool-proof, universally applicable method and will never be supplanted in small shops.

Liquid baths for carburizing are also of increasing importance. The earlier difficulties with these activated baths have been overcome to a surprising extent; work quenched in oil from such baths formerly required an acid rinse to remove insoluble residues, but many compositions now clean up well in hot water. Bath stability and fluidity have been improved, so that for the range of case depths from 0.010 to 0.030 in. the use of media of this type is deservedly increasing.

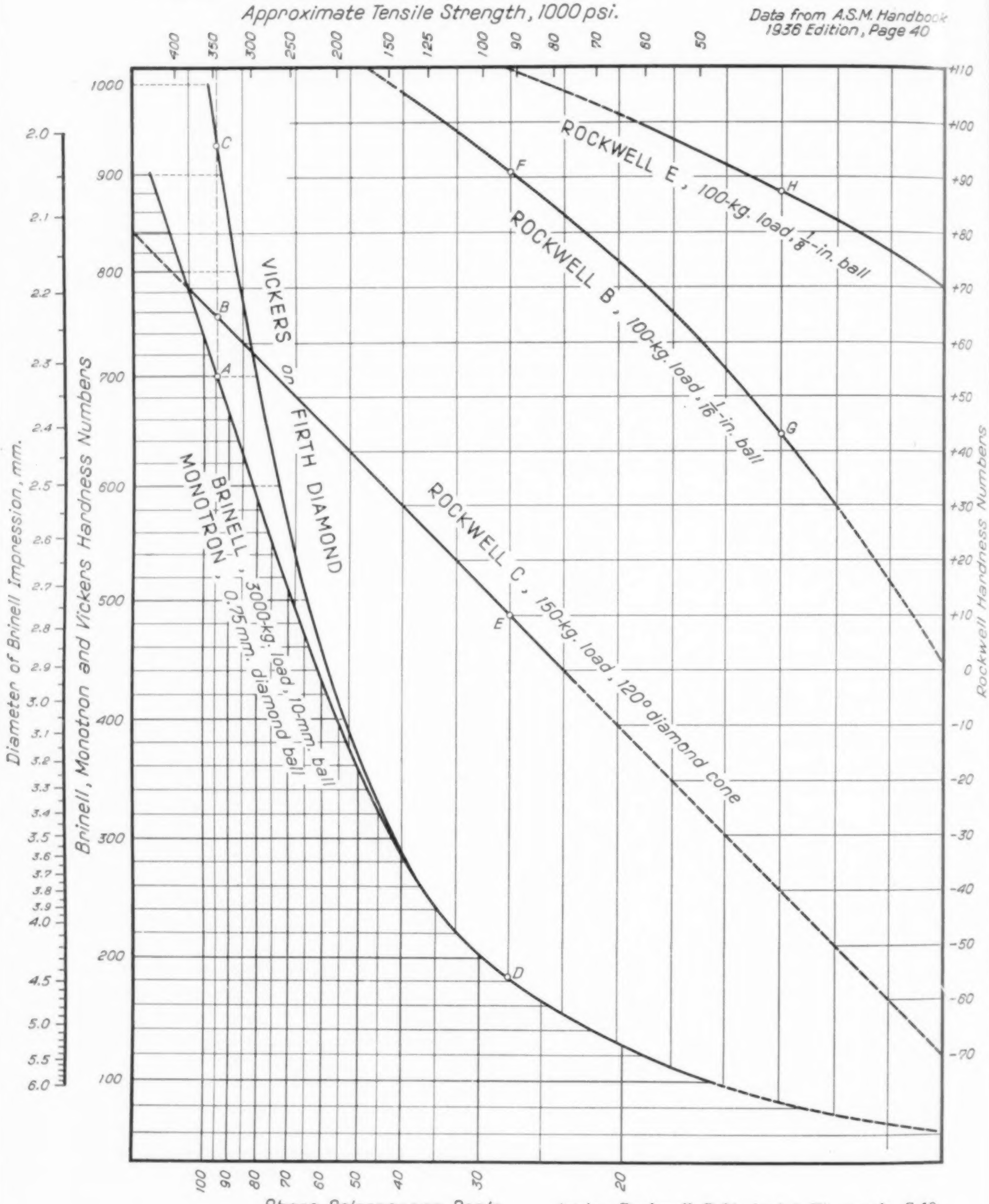
Metal Coating By Cementation

By M. D. Sarbey
Cooper Products, Inc., Cleveland

COVERING a foundation metal with some other metal by means of cementation is a relatively old art, and well known for certain specific applications. Thus the coating of steel with zinc by "sherardizing", with aluminum by "calorizing", and even the much older process of coating iron with steel by "case hardening" are all examples of this art. Each of these commercial processes has its advantages and its limitations. In recent years considerable research has been done and progress made in the use of this principle to apply coatings containing chromium and silicon, singly or in combination, to a foundation of iron or steel for the development of superior resistance to tarnish, oxidation, or chemical corrosion inherent in the iron-chromium and the iron-silicon alloys.

In the early work on chromium coating (or "chromizing" as it is now called) the article was embedded in powdered chromium and heated in a protective atmosphere like hydrogen. Depth of penetration of the chromium into the steel depends on the temperature and duration of the treatment. Heating at about 2000° F. for about 4 hr. produces a penetration of about 0.005 in.,

Hardness Conversion Chart for Steels



Verticals represent equivalent hardness.

For instance: Brinell or Monotron 700 (point A) equals Rockwell C-65 (point B), equals Vickers 930 (point C), equals Scleroscope 94 (bottom scale), and about 340,000 psi. tensile (top scale).

Again: Rockwell B-91 (point F) equals C-10 (point E), equals Brinell, Monotron or Vickers 184 (point D) and Scleroscope 28, and has about 92,000 psi. tensile strength.

Finally, Rockwell B-43 (point G) equals E-87 (point H). Curve for latter scale is from Bureau of Standards Research Paper No. 185.

while treatments at 2350 to 2450° F. for 24 to 48 hr. cause the penetration to approach ⅛ in., which appears to be the maximum.

The expensive combination of high temperature and hydrogen atmosphere used in the early work limited very greatly the size of the furnace and the commercial practicability of the process. This is probably the principal reason why it did not come into general use long ago.

In the more recent work it has been found that certain auxiliary materials such as ammonium chloride, chlorinated lime, and sodium chloride can be added to the chromium powder to great advantage. The chemical and (probably) physical action of these addition agents aids the penetration of chromium and — providing the articles under treatment are completely enclosed to prevent access of air — it also avoids the use of a hydrogen or other protective atmosphere. This removes the limitations on furnace size and construction, and permits chromizing in equipment very similar to standard heat treating furnaces.

The coating is not pure chromium but an iron-chromium alloy. This alloy is not uniform in composition but is richest in chromium at the extreme exterior, containing about 50% chromium at that point, and tapering off gradually toward the interior. The useful part of the coating averages about 27% chromium. The coating produced is not superimposed, but is an actual penetration of the steel by chromium. The chromized pieces increase in size by about 10% of the thickness of the coating.

Carbon in the steel reduces the penetration so that coatings of ponderable thickness can be produced only on steels containing less than about 0.30% carbon. (New chromizing mixtures have been developed, however, that chromize satisfactorily steels up to 0.70% in carbon.) Chromized coatings are not particularly hard, about 250 Brinell, but by suitable treatment can be hardened to above 500 Brinell. The long heating incident to the process of course affects the foundation metal, which for many purposes must later be normalized. Under suitably controlled conditions the coatings are workable, so that chromized bars may be worked into sheets and wires with thin but continuous alloy skin.

Powdered silicon-chromium alloys can be used for cementation in place of pure chromium, in which case a ternary coating of iron-chromium-silicon is produced. This requires lower temperatures and the coating composition can be controlled within certain limits.

In a generally similar way pure silicon can be used for cementation, producing iron-silicon coatings. These require still lower temperatures, 1800 to 2200° F., and much greater depths of penetration can be produced. Siliconized coatings are more brittle however.

These new coatings are believed to be not too expensive for considerable industrial production. Even under present conditions suitable steel articles can be chromized at 10¢ to 15¢ per lb. For siliconizing the cost is probably considerably less, but increased volume and experience can greatly reduce present costs.

Differential Hardening

Induction and Flame Heating of Surfaces

By H. B. Knowlton
Metallurgical Engineer
Gas Power Engineering Dept., International Harvester Co.

DURING THE PAST YEAR there seems to have been an increasing interest in the application of induction and flame heating of surfaces for producing local hardness of articles made of medium carbon steel.

At the last ⊕ convention it was brought out in the paper by Messrs. Burns, Archer and Moore that the maximum hardness obtainable in thin sections was the same for all steels from about 0.60% carbon up. In other words, if the section heated and quenched is sufficiently small it should be possible to obtain as high a hardness with 0.60% carbon as with steel of higher carbon content.

The flame and induction heating methods were utilizing this principle even before the publication of the paper mentioned above. In these methods the surface layer only is heated, and heated rapidly. The depth of the layer heated to above the critical point is frequently ⅛ in. or less. Cooling is extremely fast due to the fact that heat is abstracted both by contact of the surface with the quenching fluid and by conduction into the unheated center portion.

It is easily possible, therefore, to produce the high hardness of a casehardened steel on the surface, and the strong, tough physical properties of a heat treated medium carbon steel in the center of large sections. The steel employed may be a medium carbon steel with little or no alloy additions. This method is being used to commercial advantage for producing local surface hardness on fairly large parts such as

crankshafts. It is also being used on quite small parts, such as gears for adding machines.

The writer is inclined to believe that this is one of the most important of the comparatively recent developments in the science of heat treating. It is expected that in the future there will be a much wider application of this principle of local heating.

Heat Treatment of Cast Irons

By Garnet P. Phillips

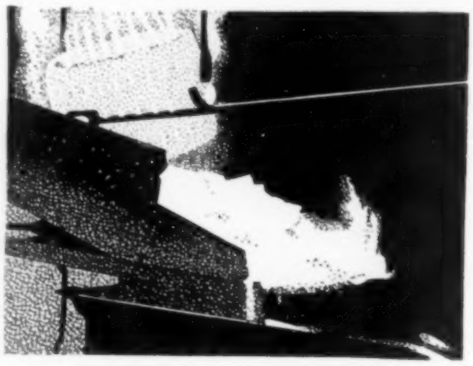
Foundry Metallurgist, International Harvester Co., Chicago

HEAT TREATMENT of cast irons other than malleable can be resolved into three broad classifications: *(a)* Treatment for stress relief, *(b)* for softening, *(c)* for hardening.

The first and second types of treatment are frequently combined when it is desired to relieve all internal stresses present in the as-cast condition and also to lower the hardness for increasing machinability. Castings that are to be hardened are always stress relieved when accurate dimensions must be held. In addition many castings are annealed (softened) prior to machining and hardening so that all three types of heat treating are frequently employed on a given type of casting.

Stress Relief — For many years it was customary to "age" castings to relieve internal stresses, the process being just what the term implies. The process was effective but time consuming and, in the present day, impractical. The relief of internal stress may be accomplished at almost any temperature — the time employed being in an inverse ratio. At ordinary room temperature months or years may be necessary. In present day practice stresses are relieved by heating to 900 to 1100° F., holding one hour per inch of section, and then cooling relatively slowly. (The higher temperature is employed with the more stable cast irons.) The practice results in practically no decrease in hardness; the results obtained are dimensional stability and increased strength.

The terms "stress relief", "aging" and "normalizing" are all employed by foundrymen to describe this type of heat treatment. "Normalizing" is perhaps unfortunate, as the metal is not heated to or above the critical temperature, as would be inferred from the word.



Softening — This type of treatment is universally called "annealing" and consists of heating at temperatures from 1100 to 1650° F. or higher, holding a minimum of one hour per inch of section, and cooling relatively slowly. The maximum temperature may thus be below or above the critical temperature range. The effect on gray irons is to decrease hardness and strength by an amount depending on metal composition, temperature and time. The lower carbon irons and irons containing carbide stabilizing alloys are affected least for any given annealing cycle. As an example, a cast iron with 21% chromium and 2% carbon is annealed at 1850° F.

Hardening consists usually of heating to above the critical range, holding to assure uniformity of temperature in the casting, quenching in oil to cause the austenite to transform to martensite, followed by drawing or tempering. Temperatures employed on gray irons and alloy gray irons usually are in the range of 1475° to 1575° F. Tempering may range from 350° F. to (usually not over) 600° F., depending on final hardness and strength desired, although there are exceptions. Hardness values up to Rockwell C-58 may be obtained by oil quenching alloy irons of proper composition.

Irons hardened are usually pearlitic as-cast and generally are alloy irons fairly low in total carbon (2.80% to 3.20%). Alloys are usually nickel, chromium, molybdenum and copper, alone or in various combinations and percentages. The castings must be of such design that the stresses built up on quenching will not cause failure. Occasionally castings are water quenched for abrasion resistance.

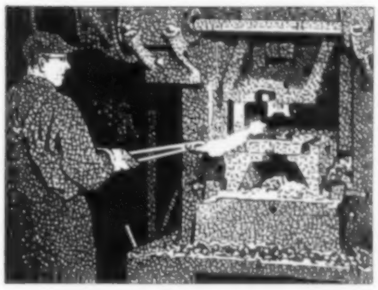
Another type of hardening treatment is the "annealing" at about 1000° F. of special alloy irons (6.50% Ni, 3.75% Mn) that are austenitic as-cast to obtain Brinell values of around 400.

The heat treatment of cast irons is becoming more and more common. There is a chance that annealing treatments will increase at the expense of alloy content. The use of hardened gray irons is growing with demand for greater wear resistance in castings of moderate price, and this will probably lead to a proportionate consumption of alloying metals.

FORGING AND FORGING MACHINERY

METAL PROGRESS
OCTOBER 1938

Forgings and Forging Machinery



Drop Forgings in Steel

By R. W. Thompson
Sales Engineer, Transue & Williams Steel Forging Corp.
Alliance, Ohio

IN THE FACE of strong competition from alternative methods of construction, the remarkable achievements attained by steel forgings in all branches of the transportation and equipment industries are a testimony to their quality and perfection. The trust which designers and users place in drop forgings has resulted from a long period of satisfaction, made possible by their proven ability to withstand the stresses and fatigue imposed upon modern equipment.

Producing drop forgings to meet these exacting service requirements is not the operation of heating a bar of steel and then hammering it between a pair of dies to produce a given shape. Each step or detail from the time the part is represented by a few lines on a blueprint until it is a finished and approved forging results from engineering control and planning.

The steel mill is advised at the time of purchase of material of the nature or use of the forging as well as the ultimate physical expectancy demanded. The mill is then enabled to furnish steel with whatever limitations of the chemical elements and control of microstructure are essential. To insure the forger that the steel will meet the specifications, representative bars or billets are examined for both micro- and macro-structure and checked for grain size. Tensile tests, bend tests, and impact tests are cut from heat treated samples to prove definitely the suitability of the material before it leaves the mill.

Inspection of the raw material does not end at the steel mill. The modern forging plants have their own inspectors and laboratories and upon receipt of the steel a re-check is made, providing double assurance that the material is satisfactory for the application intended.

It is easily understood how these forging bars after being carefully heated to just the right plastic condition are further refined by shaping them in dies which are themselves designed for the proper reduction and flow of hot metal.

Judgment of quality of a drop forging is not guess-work. Test prolongations may be forged integral with the part and thus provide a means of checking the physical and structural qualities of *every* piece, if desired. Examination after deep etching will determine if the flow fibers are in a position to give the greatest strength and resistance to stress. Since the flow fibers are controlled by the die design, all forgings made from them will have comparable internal structure in this respect.

The high quality standards developed in drop forgings have promoted their increased use and have made possible the mechanical efficiency of many new items of equipment. Their strength and ductility, controlled by heat treatment of selected analysis of steel, can be made to conform to the requirements of any type of service.

The future will see larger and heavier drop forgings, principally because of the increase in speed demanded by our transportation systems. The development of new types of steel will create uses for drop forgings unknown to us at the present time. The value of the drop forging in the economic development of the future may be expected to be even greater than it has been in the past.

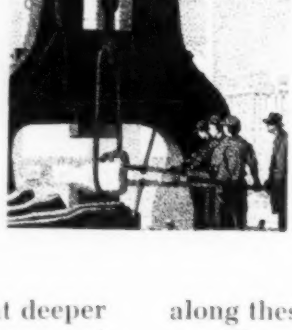
Forging Machinery

By Ernest E. Thum
Editor, Metal Progress

DEPRESSED economic conditions in America have been balanced in part by an increased demand from abroad, and this has avoided stagnation in the industry that manufactures forging machinery. The outstanding feature of this export business is the large size of the machines ordered, possibly for the manufacture of large aircraft. It is estimated that the forging industry in several European countries is now as well or better equipped for making very large drop forgings than we are in this country. However, none other approaches the United States in production of medium range of work, and in equipment therefor — say hammers rated up to 12,000 or 15,000 lb.

This does not mean that no large hammers have been made for American shops. One notable instance is a 35,000-lb. steam hammer, with four-corner ram guides, accommodating dies up to 12 ft. long and used for forging diesel crankshafts. These shafts have bearings up to 9 in. diameter, are drop forged in one plane, the 8 to 16 throws are twisted to correct angularity on a special bending machine, and a coupling flange up to 18 in. outside diameter formed on the end by an upsetting forging machine of gargantuan dimensions.

Trends in forging machine design continue toward greater rigidity, more accurate die alignment, increased power and speed, and ease and convenience of operation. Longer header slides with greatly increased wearing surfaces, together with improved die slides and more rigid clamping action, generous crankshafts or the entire elimination of cranks in favor of eccentrics — all these things have made for upset forgings of smaller tolerances. Improved clutches, air operated, air cooled, are essential features. Electric, air and hydraulic machine controls and stock handling devices are receiving much attention.



Higher speeds tend toward improved die life, due to the shorter time of contact between hot steel and cold die. It also seems that deeper die impressions can be filled at higher speed than at slower. Greater production comes from machines stout enough to form a forging in two or three blows rather than three or four. Small forgings in multiples, made from blanks hot from the rolling mill, have set a new record.

Accuracy in hot forging dimensions has warranted an extension of the practice of pressure finishing in presses of great power and precision. Done cold, as a coining operation, the forging is so close to dimension as to eliminate all rough machining. Forging on presses also makes for closer tolerances, less flash and smaller draft angles (or no draft at all, if proper ejector devices are included).

Power and accuracy in the forging machinery, as well as correct die design and heating practice, is necessary to give the correct flow of the "grain" or "fiber" of the metal — a matter which may double the reliability of the forging. If properly done, piercing aids this flow of metal for greater strength, as well as saves the metal in the hole that is pierced. "Piercing" here is used in a different sense than merely extruding the metal from the hole. If the forging is properly pierced off the bar, there will be no waste or nubbin of metal — only a small fin.

Massive Forgings

By J. L. Cox
Chief Engineer, The Midvale Company
Nicetown, Philadelphia

THE PERIOD of uncertainty through which we are passing has been discouraging to new enterprises as well as to the considerable expansion of those already existing.

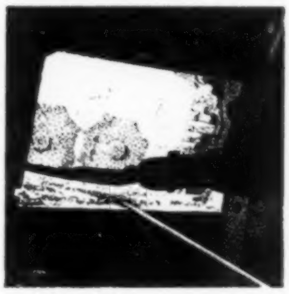
It results that little new equipment has been installed in this country by the heavy forgings industry, although at least two concerns are fitting themselves to produce weldless rings up to 30 or 40 ft. in diameter, for which there is a very small demand. Heretofore the largest weldless ring that could be rolled was said to be 15 ft. in diameter by 4 ft. in width. A ring wider and slightly larger in diameter could be made by the largest forging press.

The national petroleum and chemical industries have added comparatively little to their equipment of large forged autoclaves. There is more activity abroad, and some business done along these lines, notably with Japan.

The public service corporations have not been encouraged to invest in additional facilities, and a large potential demand from them for heavy turbine forgings lies dormant.

Interest appears to be quickening in the use of thick-walled steel cylinders as storage reservoirs for air-hydraulic accumulators, with pressures running up to 3000 psi., in place of the conventional type of accumulator loaded with dead weights. It is claimed that a considerable economy may result.

The demands of the expanding Navy have required some large work, with larger yet to come, but forgings for marine power plants are small in these days of the high speed turbine when compared with those of the slow speed reciprocating engine.



The greatest recent activity in the steel industry has been the installation of continuous wide strip mills by numerous plants. When used for the production of cold rolled, highly finished products they require forged steel rolls of exceptional size. Rolls as large as 32 in. diameter by 110 in. face, hardened to 100 scleroscope or more, ground and polished, have been made for the rolling of aluminum. The manufacture of such rolls is a metallurgical achievement of the first order.

Inserts in Forging Dies

By George A. Smart
Consulting Engineer, The Acme Machinery Co.,
Cleveland

AS WAS WELL SHOWN in the article last month "Forgings for Aircraft", industry is today demanding far more from the producer of forgings than it did 15 years ago. Commercial forgings, that is, forgings such as are used by the agricultural and automotive industry, are today being produced without much difficulty, but it is with the so-called special or precision forgings that he is being called upon to use all the ingenuity at his command.

Just what are these requirements that industry has been imposing? They may be classified as follows:

(a) Weight tolerances, such as a limit of 1 or 2 oz. on forgings weighing from 2 to 4 lb.

(b) Size tolerances, such as limits of plus or minus 0.010 in. or even less, on overall dimensions where subsequent coining or machining operations are required.

(c) Nature of design, such as small fillets, thin sections, abrupt sectional changes, and surfaces on different planes, necessitating difficult locks in die design.

(d) Introduction of alloy steels which do not forge or flow readily even in their plastic state, such as steels with high chromium content.

(e) The elimination of excessive draft angles — that is, reducing the customary draft of 7° or 10° to 3° or 5° or, in some instances, none at all.

Manufacturers of forging machinery have fortunately come to the aid of the drop forger by giving him production equipment that stays in adjustment longer, and is easier to adjust when that finally is required. Manufacturers of die steels have also been busy, producing alloy toolsteels of greater abrasion resistance and longer life.

These high grade non-warping toolsteels are rather expensive, and hence the die designer is turning them to use as inserts in larger blocks of less expensive, softer steel. This may be done for dies either for drop hammers or forging machines. The inserts, properly hardened, may be either shrunk or keyed in place. Shrinkage allowances should be about 0.002 in. per in. up to 6 in., and 0.0015 in. per in. for larger ones. Holders should be heated to about 850° F. and the insert placed in position. When worn so much it needs replacement, the die can be reheated and the insert loosened by a jet of cold water applied to its face. A hole previously drilled through the holder to the center of the insert cavity allows the insert to be driven out.

While the production superintendent still desires something more from these inserts, considerable can be done to enhance their durability by taking the following precautions:

(a) Proper forging of the insert — that is, accurate control of forging and annealing temperatures. In this connection, it has been also found advisable to forge some inserts so that the flow lines or fibers of the toolsteel are at right angles to its length. This has been found to work out to a great advantage in connecting rod inserts that are prone to crack along the I-beam section.

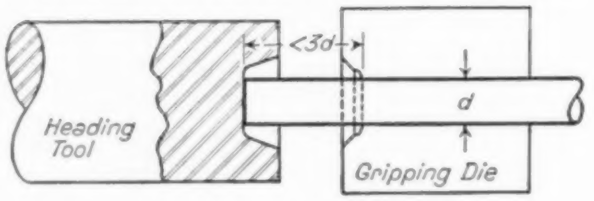
(b) Proper heat treating of the finished insert. Never try to save time in this operation, for if the piece is not thoroughly soaked at the correct quenching temperature, it may fracture on quenching. The insert should be properly drawn so as to relieve all possible quenching strains.

(c) Precautionary pre-heating of the insert before starting to run the forgings. This is very seldom overlooked in the drop hammer, but should also be done in the upsetter. Subjecting one surface of a cold insert to the hot steel being forged

Rules Governing Forging Machine Dies

(Adapted from E. R. Frost; Courtesy National Machinery Co.)

Rule I — The limiting length of unsupported stock that can be gathered or upset in one blow without injurious buckling is three diameters.

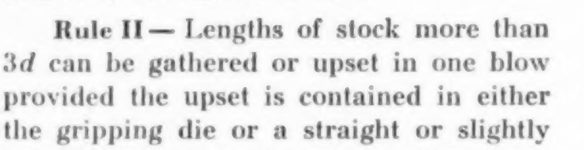


Note. *(a)*: A safer maximum length is $2\frac{1}{2}d$; little attention need be paid to squareness of end if $l=2d$. If $l>3d$, buckling will occur near the middle of the unsupported length. These principles hold irrespective of whether the stock overhangs the face of the gripping dies, or whether any portion is gathered in either gripping dies, heading tool or both.

Rule II — Lengths of stock more than $3d$ can be gathered or upset in one blow provided the upset is contained in either the gripping die or a straight or slightly tapered hole in the heading tool, and the diameter of the upset made in that blow is not more than $1\frac{1}{2}d$.

Note *(a)*: Multiple buckling will be checked by contact with sides of the die, and friction therewith will cause a fin to form around end of upset. Such long upsets cannot be made half in one die and half in the other, for central buckle will receive no side support.

Note *(b)*: A safer maximum is $1.3d$, and if Rule I is also applied, the upset will be free from end fins.



Note *(c)*: For very long upsets, it is helpful to have the end of the bar at a lower temperature, and to have a minimum diameter upset for the outer half of the die, the inner half tapering 4° to wider diameter at the base.

Note *(d)*: In upsetting tubing, wall thickness cannot be increased externally more than 25% at one blow; internal upsets are almost unlimited because arch effect prevents internal buckling.

Rule III — For upsets requiring more than $3d$ in length of stock, and in which the upset is $1\frac{1}{2}d$, the amount of unsupported stock beyond the face of the die must not exceed $1d$ (operation 1, at right).

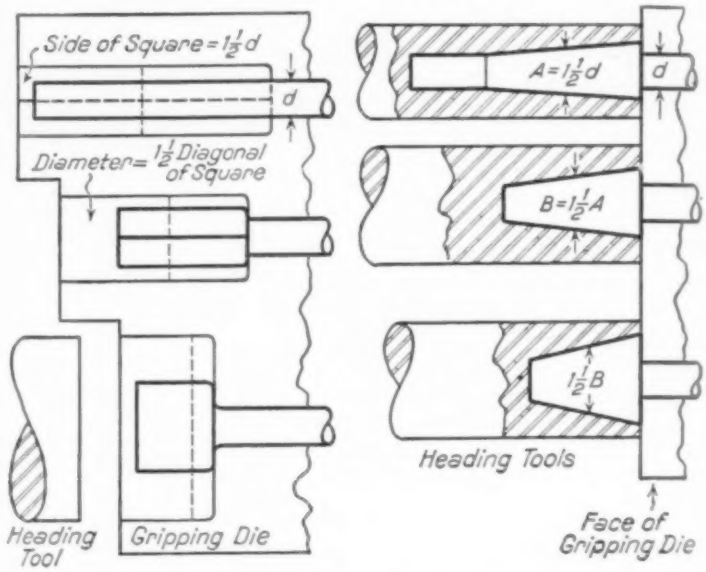
Note *(a)*: Unsupported stock can amount to $1\frac{1}{2}d$ if diameter of upset is reduced to $1\frac{1}{4}d$.

Rule IV — Large amounts of stock can be gathered by multiple application of Rule II and III, and by using square or tapered impressions.

Note *(a)*: In making the wide flange in sketch at left, below, the first and second impressions are within the $1\frac{1}{2}d$ limit, but the third, being a short upset under Rule I, is unlimited in diameter.

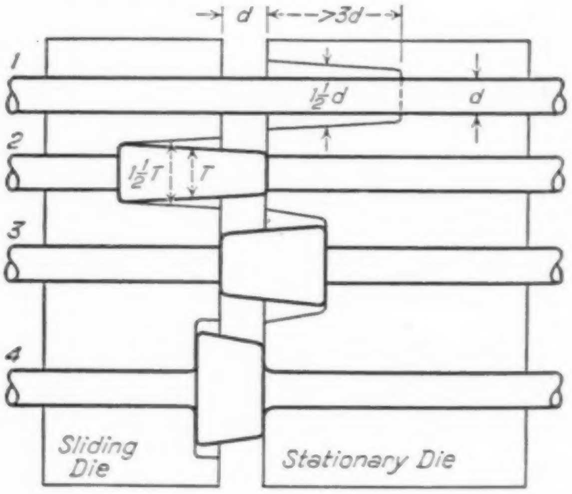
Note *(b)*: The side of the square may be $1\frac{1}{2}d$ of the original bar, and the diameter of the next round may be $1\frac{1}{2}$ times the diagonal of the square.

Note *(c)*: Tapered holes are proportioned as to their diameters at midlength of unsupported stock.



Rule V — Sliding dies, for upsetting stock at some distance from the end of a bar, are governed by all the above rules.

Note *(a)*: Friction along the sides of the sliding die will favor upsetting near its front end, so multiple impressions should be alternately in front and rear half, or alternately in sliding die and gripping die, as shown in sketch below.



very often causes it to break.

(d) Correct forging practice. By this is meant the proper breaking down or roughing operations of the piece being forged, before it is placed in the insert for the finishing operation. If the piece has been properly roughed out, there will be less extrusion of the metal over the insert surfaces and a small amount of extruded surplus metal or flash.

There are still many instances where, if the metallurgist could provide the proper toolsteel, a large number of pieces could be forged to an advantage. Take for instance, the forging of stainless steel turbine blades. Considerable time is involved in machining these blades, either from solid stock or from rough forgings, and it should be possible to forge these blades to very close tolerances. While this has been attempted, the die maintenance is so great that no money savings have been made.

Again, if it were possible to obtain a toolsteel that would stand up, many upset forgings could be made by the single pass method, such as is now used in the continuous forging of balls wherein the stock is upset and just fills the die impression without any abrasive action. In a small bevel pinion or gear the metal flows over the surfaces of the dies as it is being extruded into the impression, and the resultant die life is very short.

Fuels, Heat Control and Instrumentation

By Martin J. Conway
Fuel Engineer
Lukens Steel Co., Coatesville, Pa.

AMONG the myriad problems which the modern metallurgical plant must contend with, there is no doubt that combustion is of the greatest importance. From its contribution to the smelting and refining of the raw materials to the appearance and physical qualities of the finished material it is progressively becoming the manager's first assistant in its supplying to a critical consuming public its requirements in ferrous metals. These demands on combustion are continually shifting the character of the fuel supply and entail a continual analysis of the economics of application.

During the past twenty years there has been a remarkable change in the type of fuel applied to industry. This is clearly shown on page 809 of the U. S. Bureau of Mines' Minerals Yearbook for 1937. Using consumption in 1918 as a basis, the total coal consumed in 1936 had dropped to 72%, crude petroleum production had increased to 309%, natural gas to 288% and water power to 270%. With oil, natural gas, coke oven gas, and blast furnace gas replacing direct fired coal and artificial gas, the number of active gas producers has shrunk to one half of the number in use at the height of their popularity. Still further, oil is being replaced by various available gases, and lean gas is being enriched by mixture with other gases, natural, coke oven, and liquid petroleum gases. Extensive pipe line systems have made available the liquid and gaseous fuel to industries far removed from the source of supply, at a transportation cost per thousand "therm-miles" of approximately half that of railroad transportation.

This change in fuels has been accompanied by the invention and application of many forms of temperature and combustion control. The principal advantages of a good system of automatic control include:

1. Fuel saving.
2. Saving of time and labor ordinarily wasted in adjusting combustion equipment and watching indicating temperature instruments.
3. Minimized losses due to spoilage, including material, time and labor.
4. Possibility of increased production.
5. Advantage due to more uniform and improved quality production.

The real objective of all these considerations is a reduced over-all manufacturing cost. While the first cost of the installed control equipment is a considerable item, if properly applied and maintained it does not take long to make up its cost in savings, particularly by fuel economy, but to depend on this as the

Standard Tolerances for Forgings up to 100 Lb.

Adopted by Drop Forging Association, 1937

TOLERANCES, within the scope of these standards, shall be either "special" or "regular."

Special tolerances are those particularly noted on the drawings or in the specifications, and apply only to the particular dimension or thing noted. They may state any or all tolerances in any way as occasion may require. Regular tolerances apply in all other cases.

Regular tolerances in general forging practice are known as (*a*) "commercial standard," for general forging practice, or (*b*) if extra close work is desired involving additional expense and care in the production of forgings, "close standard" may be specified.

Class I—Thickness Tolerances

For drop hammer forgings, thickness tolerances shall apply to the overall thickness measured in a direction perpendicular to the fundamental parting plane of the dies.

For upset forgings, thickness tolerances shall apply to the metal actually enclosed and formed by the dies, measured parallel to the direction of travel of the ram.

Thickness Tolerances in Inches

Max. Net Weight	Commercial		Close	
	Minus	Plus	Minus	Plus
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1	0.012	0.036	0.006	0.018
2	0.015	0.045	0.008	0.024
3	0.017	0.051	0.009	0.027
4	0.018	0.054	0.009	0.027
5	0.019	0.057	0.010	0.030
10	0.022	0.066	0.011	0.033
20	0.026	0.078	0.013	0.039
30	0.030	0.090	0.015	0.045
40	0.034	0.102	0.017	0.051
50	0.038	0.114	0.019	0.057
60	0.042	0.126	0.021	0.063
70	0.046	0.138	0.023	0.069
80	0.050	0.150	0.025	0.075
90	0.054	0.162	0.027	0.081
100	0.058	0.174	0.029	0.087

Class II—Width and Length Tolerances

Width and length tolerances shall be alike, and are classified in three subdivisions (*a*) shrinkage and die wear tolerance, (*b*) mismatching tolerance, (*c*) trimmed size tolerance.

For drop hammer forgings, width and length tolerances shall apply to the metal actually enclosed and formed by the die, as measured parallel to the fundamental parting plane of the dies.

For upset forgings, width and length tolerances shall apply to directions perpendicular to the direction of travel of the ram.

II(a)—Shrinkage and Die Wear Tolerances

See table below. These shall not be applied separately, but only as the sum of the two; they shall be measured in such a way as to eliminate draft or variation in draft. They apply to that part of the forging formed by a single die block, and to no dimension crossing the parting plane.

Shrinkage and Die Wear in Inches

Length or Width	Shrinkage: Commercial + or —	Shrinkage: Close + or —	Max. Net Weight	Die Wear: Commercial + or —	Die Wear: Close + or —
1 in.	0.003	0.002	1 lb.	0.032	0.016
2 in.	0.006	0.003	3 lb.	0.035	0.018
3 in.	0.009	0.005	5 lb.	0.038	0.019
4 in.	0.012	0.006	7 lb.	0.041	0.021
5 in.	0.015	0.008	9 lb.	0.044	0.022
6 in.	0.018	0.009	11 lb.	0.047	0.024
For each additional inch add	0.003	0.0015	For each additional 2 lb. add	0.003	0.0015
For example:			For example:		
7 in.	0.021	0.011	13 lb.	0.050	0.026
12 in.	0.036	0.018	21 lb.	0.062	0.031
18 in.	0.054	0.027	31 lb.	0.077	0.039
24 in.	0.072	0.036	41 lb.	0.092	0.046
36 in.	0.108	0.054	51 lb.	0.107	0.054
48 in.	0.144	0.072	71 lb.	0.137	0.069
60 in.	0.180	0.090	91 lb.	0.167	0.084

II(b)—Mismatching Tolerance

Mismatching is the displacement of a point in that part of a forging formed by one die block of a pair, from its desired position when located from the part of the forging formed in the other die block of the pair, measured in a projection parallel to the fundamental parting plane of the dies. It does not include any displacement caused by variation in thickness of the forging; mismatching tolerances are independent of and in addition to any others.

Mismatching Tolerance in Inches

Max. Net Weight	Commercial	Close
1 lb.	0.015	0.010
7 lb.	0.018	0.012
13 lb.	0.021	0.014
19 lb.	0.024	0.016
For additional 6 lb. add	0.003	0.002
For example:		
37 lb.	0.033	0.022
55 lb.	0.042	0.028
79 lb.	0.054	0.036
97 lb.	0.063	0.042

II(c)—Trimmed Size Tolerances

The trimmed size shall not be greater nor less than the limiting sizes at the parting plane imposed by the sum of the draft angle tolerances and the shrinkage and die wear tolerances.

Class III—Draft Angle Tolerances in Degrees

	Drop Forgings: Outside	Drop Forgings: Inside Holes	Upset Forgings: Outside	Upset Forgings: Inside Holes
Nominal angle	7	7 or 10	3	5
Commercial limits	0 to 10	0 to 13	0 to 5	0 to 8
Close limits	0 to 8	0 to 8	0 to 4	0 to 7

Class IV—Quantity Tolerances

Any quantity shipped within the quoted limits of over-run or under-run shall be considered as completing each release or part shipment of an order. Limits are as follows:

Quantity Tolerances

Number on Order	Over-run	Under-run
1 to 2	1 piece	0
3 to 5	2 pieces	1 piece
6 to 19	3 pieces	1 piece
20 to 29	4 pieces	2 pieces
30 to 39	5 pieces	2 pieces
40 to 49	6 pieces	3 pieces
50 to 59	7 pieces	3 pieces
60 to 69	8 pieces	4 pieces
70 to 79	9 pieces	4 pieces
80 to 99	10 pieces	5 pieces
100 to 199	10%	5.0%
200 to 299	9%	4.5%
300 to 599	8%	4.0%
600 to 1,249	7%	3.5%
1,250 to 2,999	6%	3.0%
3,000 to 9,999	5%	2.5%
10,000 to 39,999	4%	2.0%
40,000 to 299,999	3%	1.5%
300,000+	2%	1.0%

Class V—Fillet and Corner Tolerances

Fillet and corner tolerances apply to all intersecting surfaces even though drawings or models indicate sharp corners. If such drawings or models have or indicate (even though actual dimensions are not specified) fillet or corner dimensions of larger radii than the following standards, such larger dimensions shall be considered as actually specified and the tolerances shall be "special tolerances."

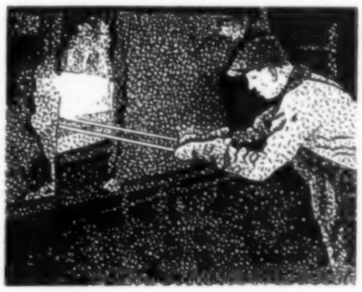
Where a corner tolerance applies on the meeting of two drafted surfaces, the tolerance shall apply to the narrow end of such meeting and the radius will increase toward the wide end. The total increase in the radius will equal the length of the drafted surface in inches, multiplied by the tangent of the nominal draft angle.

Fillet and Corner Tolerances

Max. Net Weight	Commercial	Close
0.3 lb.	3/32	3/64
1 lb.	1/8	1/16
3 lb.	5/32	5/64
10 lb.	3/16	3/32
30 lb.	7/32	7/64
100 lb.	1/4	1/8

only way of making up the cost is an erroneous method of estimating the rate of return. Experience has proved that the true savings in cost of finished product are often many times greater than the fuel savings only.

Careful consideration must be given to the control installation details, the apparatus must be properly fitted to the process which it is to control, and provision must be made for checking and keeping it accurate.



Intimately connected with this maintenance of accuracy is the question of mechanical robustness and continuity of accuracy. Where numerous controls are in operation, a card system providing a complete case history of each piece of equipment is helpful when deciding on the purchase of new equipment.

With the possibilities of analysis equipment which interpret conditions and transfer these interpretations to the control equipment with the minimum time lag, we can now assure the consumer that the product he is purchasing is uniform in quality, and, if necessary, deliver to him the forge shop control records with his bill of lading.

Heating of Forgings

By J. B. Nealey
Director, Industrial Gas Publicity, American Gas Assn.
New York

WHILE A NUMBER of machines for the production of non-scaling atmospheres have been developed for many types of furnaces, principally for heat treating, they do not seem to have been successfully applied in combination with forging furnaces as yet. In this and other fields the controversy as to the relative merits of the long and short (or luminous and clear) gas flame has brought out more information. Some of the more important claims for the long or luminous flame are: An increased rate of heat transfer, more uniform temperature, less costly refractory maintenance, and reduction in the amount of oxidation or scaling. Advantages claimed by the proponents of the clear flame include: Better control of furnace atmosphere, less combustion volume required, lower initial cost, and elimination of smoke. The writer would tentatively state that clear flames seem to be more advantageous in smaller furnaces while luminous flames are better in larger installations.

A forge shop of a plant making automobile parts recently tried to solve this problem. Some 45 slot-type furnaces were available for study, and a large number of burners were used either alone or in combination. Neither the straight inspirator, non-luminous gas flame or the highly luminous diffusion gas flame met the maximum requirements. Various schemes of introducing partially burned or "cracked" gas to condition the atmosphere were eventually discarded. Eventually a burner which used a combination of oil and gas led to success. The heavy hydrocarbons in the oil are readily broken down by the heat of the gas flame, and the combination becomes highly luminescent. While turbulence is to be avoided in the conventional gas flame, in the combination gas-oil flame it very probably proves an advantage.

Shops that are producing quality forgings find that it well pays to keep furnaces in good shape. Pyrometric control is always found on through furnaces (either straight line or turret) where stock is delivered at a steady rate at a pre-determined temperature. Many forge superintendents believe that such instruments are as essential in slot furnaces. All know that an overheated billet always makes a poor forging and an underheated billet also wears out the dies. Consequently the trend toward correct instrumentation is well defined.

Surface Cleaning

By John A. Webber
Production Manager, Interstate Drop Forge Co.
Milwaukee, Wis.

WHILE there do not appear to have been many changes or advances in the field of surface cleaning and finishes of forgings in the last few years, two such developments do come to mind.

Small batch type cleaners have recently come on the market. In these machines the grit is thrown by centrifugal force, which eliminates the necessity for high pressure air. This, combined with the small units which are being made, has filled a very definite need in the commercial forge shop for cleaning small batches of forgings.

Another development, the use of which the writer believes will be further increased in the future, is electrolytic pickling. This method, while more expensive than ordinary acid pickling, has the advantage of removing scale without pitting or attacking the steel itself, and, which is more important, it shows up very clearly any external defects. This the writer believes will become more important as the necessity for absolute freedom from surface defects becomes more widespread, as in the use of airplane parts.

This method is being used at the present time in conjunction with the flash plating of tin for parts which are used on the inside of internal combustion engines. The tinplate assures an absolute freedom from any adhering scale which might later come off to scour or injure the inside of the motor. It will also probably be very advantageous for careful inspection since it also shows up clearly any external defects such as seams, laps, or cold shuts.

Light Metal Forgings

By A. A. Handler
Aluminum Company of America
Cleveland, Ohio

THE USE of aluminum alloy forgings in aircraft and in many other fields has enjoyed a steady and continuous growth in the past few years. This gradual growth is fortunate, because it has stimulated the development of the art. It is interesting to note that it was necessary to develop the materials to produce the forgings at the same time that the forging art was being worked out. The fact that these two problems were carried along simultaneously has contributed greatly to the good reputation the product enjoys.

While most people are well acquainted with forged aluminum alloy propeller blades because of the conspicuous place they occupy, there are many other airplane applications which are not so well known. The crankcases and pistons of practically all radial engines are aluminum alloy forgings. Many structural fittings throughout the airplane are also forged. The development of this application has been quite rapid until it is now common to use as many as 50 different sets of dies to produce fittings for a single type of plane. Size and intricacy of these fittings have increased steadily.

Different types of aluminum alloys have been required and provided for these various applications, each alloy having properties that make it particularly suitable for its specific use. For instance, an alloy developing a minimum tensile strength of 65,000 psi. is widely used for structural fittings, while other alloys which retain a large percentage of their strength at elevated temperatures are used for pistons.

Aluminum forgings are finding increasing use in the chemical, food and brewing industries because of the superior resistance of one of the newer alloys to these special types of corrosive conditions. Other factors, such as cost, appearance and, of course, light weight combined with proper strength, have extended the use of forgings in such portable equipment as typewriters, hand tools and surveying instruments.

An interesting recent development has been the production of aluminum alloy forgings by the hot press method, both in mechanical and hydraulic presses. Many small parts are produced on this type of equipment to very close dimensional tolerances.

The use of magnesium and its alloys for forged parts is also assuming increasing importance. While the development of the art has progressed steadily in this country, the application of magnesium alloy forgings has been more general in Europe than here. Metallurgical development has made a variety of attractive alloys available, and the use of these materials is certain to increase.

Forging the Nickel Alloys

By Fred P. Huston
Development and Research Division
International Nickel Co., New York

NICKEL and the trade-named nickel alloys, Monel and Inconel, can be forged readily in dies or by hand methods into almost any shape that can be forged in steel. Successful forging depends largely upon proper heating. Exposure of high nickel materials, when hot, to sulphurous atmospheres or other sources of sulphur must be avoided scrupulously.

Oil is the fuel most generally used by forge shops. It should be purchased on a specification limiting its sulphur content to 0.5% max. Gas is more appropriate and should always be used if available. Two other very satisfactory fuels are butane and propane, and while their cost on a B.t.u. basis is higher than that of oil, their ultimate cost per pound of finished forgings may easily be lower. The solid fuels are generally unsatisfactory because of the difficulty of providing for *(Continued on page 485)*

Forging the Nickel Alloys

(Cont. from page 476) proper heating conditions (atmosphere), inflexibility in heat control, and the presence of sulphur in excessive amounts.

The furnace should be maintained about 50° F. higher than that at which the work is to be "pulled", and in no case should it be pulled at less than 2000° F. The proper length of time to heat nickel and its high alloys is the minimum required to heat the piece uniformly.

The furnace atmosphere should be maintained continuously in a slightly "reducing" condition, with 2% or more of carbon monoxide. It is important that combustion take place before the mixture of fuel and air comes in contact with the metal.

If the forgeman has had no previous experience with the high nickel materials, and facilities are not provided for temperature control, it is advisable for him to draw out a few bars under the hammer, taking care to preserve square edges, and then to make bend tests to familiarize himself by practice with the temperature range in which the metals may be forged safely. He will find that the metals are considerably stronger and stiffer than steel at forging temperatures, and for this reason a machine worked at full load to produce a given steel forging may be incapable of producing the same forging in nickel or the high nickel alloys.

Die blocks for drop forgings or pressings may be made from either straight carbon or alloy steels. The choice between carbon steel and one of the several excellent alloy die steels available will depend largely on the shape and size of the piece, the quantity to be produced, and the material. Dies of 0.80% carbon steel, hardened and tempered to 60 scleroscope, can be expected to give a good life on the smaller forgings in nickel and Monel.

Alloy steel dies meet the needs of modern production better, and their use is almost a necessity for the larger or more intricate shapes in Monel or nickel, and for all forgings in Inconel except small and simple ones.

Trimmer dies should be made of high speed steel, with the cutting edge ground to a considerable rake. They should be set up closely enough to cut tissue paper. Trimming may be done either hot or cold.

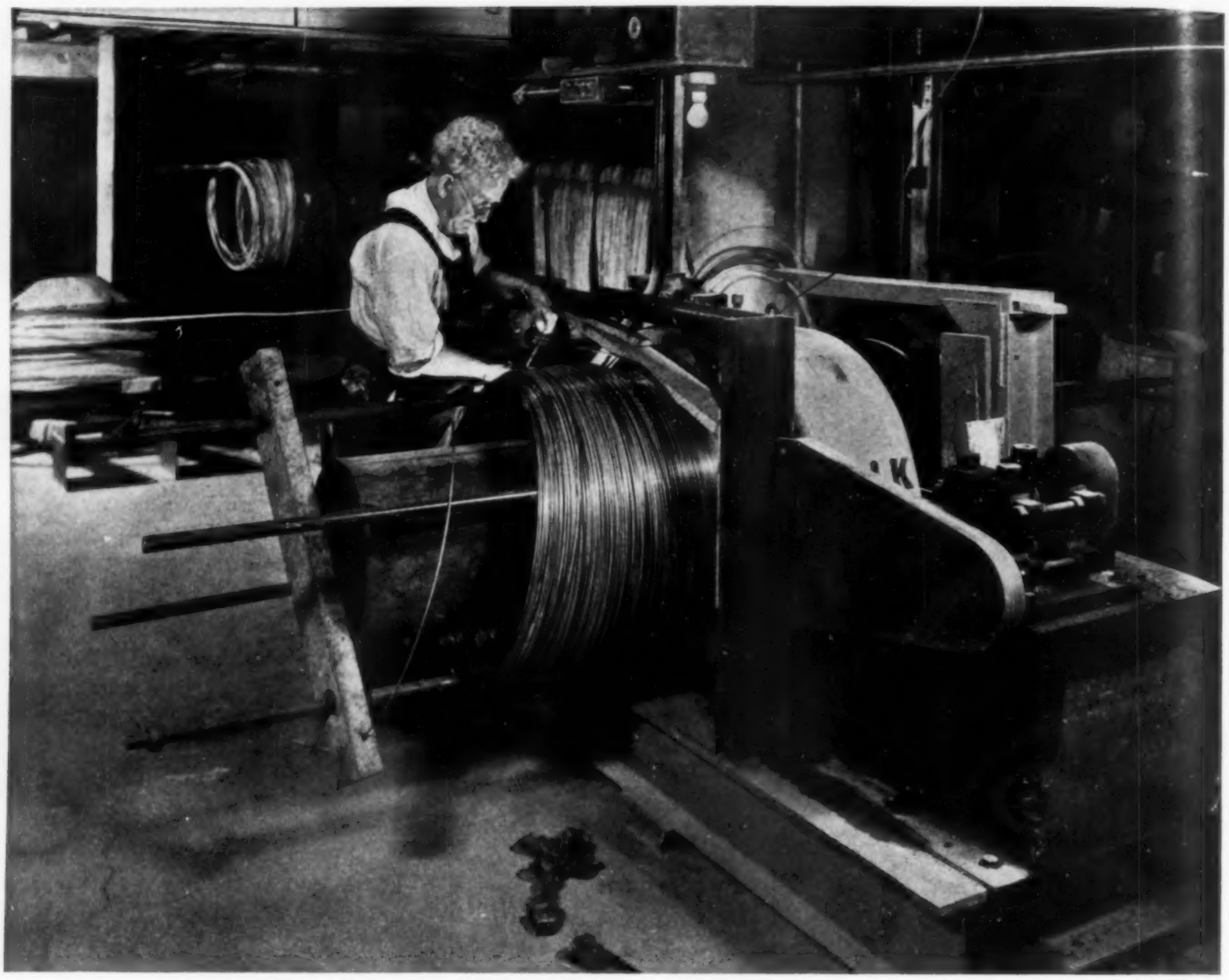
WELDING

AND

CUTTING

METAL PROGRESS

OCTOBER 1938



Whitey Sez:

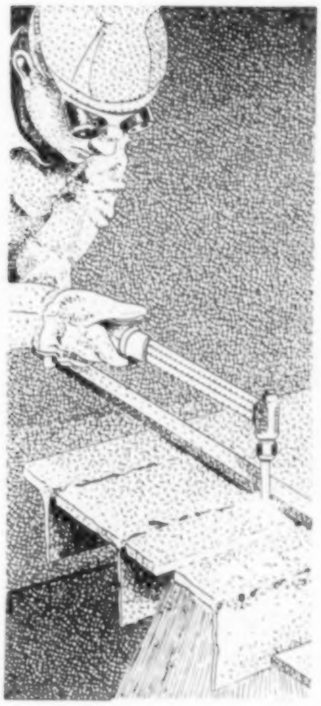
See you at the Metal Show,
Booth A-426

"This drawing unit which reduces the coils of pickled and limed wire to micrometer finished sizes, reminds me of the taxation machine working on the big fellow... he comes out shorn of his surplus, ready for a darn good melting down."

MAURATH, INC. BUILDER OF BETTER WELDING ELECTRODES IN ALL ANALYSES

C L E V E L A N D

Welding and Cutting



Electric Arc Welding

By Alton F. Davis
Vice-President, The Lincoln Electric Co.
Cleveland, Ohio

THE PAST YEAR has been notable for the increasing acceptance of electric welding as a process of manufacture and construction. Adopted throughout industry, the process has been steadily extended by users who have seen benefits to be derived from wider application. Today, we see arc welding being used where a year ago some other process was employed. Moreover we find concerns who, last year, were just beginning to apply the process in fabricating parts of products, now arc welding their entire production. As result of acceptance in new fields and increased use in industries long familiar with the process, arc welding has made marked progress.

As acceptance of arc welding has increased, greater attention has been paid to factors which have a bearing on its most efficient use. Thus, we find users stressing the importance of proper technique and procedures, paying greater attention to preparation, handling and positioning of work for welding, scheduling and routing of work to and from the welders, proper training of operators, realizing the importance of using welding generators of sufficient capacity, jigs and fixtures, weld cleaning tools and other miscellaneous accessories.

Increased emphasis on welding efficiency has led to the use of larger sized electrodes to reduce welding costs. Advantage is also being taken of electrodes developed especially for fast and economical production of particular types of welds like fillets and butts.

Efficiency of welding is also aided by improvements and refinements in arc welding machines. In addition to having higher capacity and being more efficient, they are much easier to operate. They can also be readily adjusted to give exactly the right size and type of arc required, without sacrifice of penetration to welding speed or vice versa. This recent development is reflected in higher quality welds at a faster speed.

A development of special importance in the use of welding is the application of the electric arc to the welding of alloys. Extremely significant industrially because of the economies available, alloy welding is a natural consequence of knowledge gained from use of the electric arc. Alloy welding, surveyed in the light of its possible application, has only begun. In the future, it will experience remarkable progress. Quality of products made of alloy steels will be improved and their costs will be lowered in the same manner that arc welding has brought these advantages to the manufacture of products of mild steel. All metals and alloys used to any extent industrially can be arc welded today by using the proper electrode, and development of new electrodes will continue to meet the needs of industry as they arise.

Although arc welding has made remarkable progress in becoming accepted as a primary process of manufacture and construction, its present use does not begin to represent the limit of its possible application. For every place where the process is used today, there are four others, economically justified, where the process is not employed. This means that the advantages of welded construction are being obtained in only 20% of the possible applications in industry.

High Speed Welding

By F. G. Outcalt
Engineer, The Linde Air Products Co.
New York

An efficient and very fast process for automatic welding has been perfected during the past few years by subsidiary units of Union Carbide and Carbon Corp. It submerges the arc in a special welding composition, performs satisfactorily under extremely high currents and gives high quality welds at unheard-of speeds. Its many users say it has overcome the difficulties encountered in previous methods. This new process, known as the "Unionmelt" welding process, utilizes a bare wire electrode in combination with the special granulated "Unionmelt" welding composition which completely covers the end of the electrode and the edges to be welded and protects the molten weld metal from the atmosphere. The bare wire is fed from coils by means of a simply designed welding head which also serves to conduct the current to the rod and to feed the welding composition ahead of the advancing electrode. By varying the combination of welding current, voltage, and speed from a remote control station, any practical depth of penetration, width of fusion, or reinforcement can be obtained. Any commercially available thickness of metal can be welded in one pass. Welds can be made as much as 20 times faster than with any similarly applicable method. For example, butt welds can be made at 10 in. to 12 in. per min. in 1-in. steel and 5 to 6 in. per min. in 2-in. plate. The welding causes no smoke, light, or spatter, and the completed joint is remarkably clean and smooth, needing no chipping, peening, or wire brushing.

Briefly stated, the advantages of the "Unionmelt" welding process are: (1) Welds of unusual quality and strength; (2) Minimum distortion; (3) One-pass welding of thick plate at high rates of speed; (4) Simple preparation of plate edges, since straight oxy-acetylene bevels suffice for butt welding and no bevel is required for complete center overlap of fillets in reasonably thick T butt joints; (5) Smaller quantities of weld metal, since there are no losses from spatter, vaporization, and stub ends; (6) No need for chipping or wire brushing; (7) Use of bare rod from coils as the electrode.

The process has already found wide commercial use in production. Some of the largest installations have been for shipbuilding, for making center sills or other parts for railroad cars, for diesel engine frames and locomotive parts, and for longitudinal, girth, and spiral welds in pipes and all classes of pressure vessels. Automobile parts, small machinery frames, structural members, special pipe fittings, and many of the small items of manufacture produced in considerable quantities also offer a field of application.

Gas-Electric Welding

By Robert E. Kinkead
Consulting Engineer, Welding
Cleveland, Ohio

Gas-electric welding could well include the atomic hydrogen process, as well as all electric welding where the arc is shielded by gases derived from the electrode coating. For the purposes of this note, however, it is limited to the scheme where a central arc, struck from a metallic electrode, or a melt rod heated by electrical resistance, is sheathed in an oxy-acetylene flame. It was devised as a ready way to combine the accepted advantages of both arc and gas processes for fusion welding.

Until quite recently it has been generally believed that a considerable part of the heat of an oxy-acetylene flame was needed to melt the metal to be added in the form of a melt bar. That this is not true is easily shown when the melt bar is melted electrically; under these circumstances the speed of depositing metal is very greatly increased for the same gas consumption.

It is, in fact, true that the oxy-acetylene blowpipe, regardless of its many desirable properties, has very low thermal efficiency as a means of welding. The metallic arc has a thermal efficiency on the order of ten times that of the blowpipe. Where the melt rod is melted by electrical *resistance*, the thermal efficiency is on the order of 20 times that of the blowpipe (for this part of the welding operation). This

means that about 20 times as many B.t.u. must be produced by the blowpipe to melt a pound of melt rod as is required to melt a pound by electrical resistance. The reason lies in the fact that *all* of the electrical energy is used to heat the melt rod and the heat is produced *in* the metal, as contrasted to producing it externally and transferring it by conduction to the metal as is the case with the blowpipe flame.

The combination of oxygen and a fuel gas with an entrained flux as a means of shielding a carbon or metallic arc offers some possibilities in the direction of a gas shield for an arc. Here the heat is obtained primarily from the arc and quite incidentally from the blowpipe. The cost of such shielding is low.

Commercially the application of gas-electric welding remains to be developed. It appears quite adaptable to cladding operations.

Multi-Flame Welding

By Lewis F. Scherer
Assistant Chief Engineer, The Texas Pipe Line Co.
Houston, Texas

OXY-ACETYLENE WELDING of pipe lines dates from approximately 1918, but it has only been since about 1930 that the present technique has become widely employed. Occasional bad joints would be made on "blue Mondays," and definite efforts have been made toward lessening the importance of the human factor in obtaining good welds. In 1934 a three-flame tip was developed which was especially suitable for rolling welds — that is, welds made with the torch held in the down position while the joint was slowly rotated. Its success led to the investigation of multi-flame tips for making bell-hole or position welds, where the pipe is stationary. The present four-flame and six-flame tips are the result of this investigation.

The most apparent advantage in the use of this type of tip is the greatly increased speed of welding. An average increase in speed of 25% is common! When this is interpreted in welds per hour the advantage becomes obvious.

There are several inherent advantages in laying a line by the "position" or "bell-hole" method, in that it permits the construction operation to be concentrated instead of strung out along a mile or more of line. In the past full advantage of this method could not be taken because of the relative slowness of position welds as compared to rolling welds. This is now overcome as the multi-flame position weld is as fast as the former rolling weld.

Field experience also indicates a saving in gas consumption of approximately 10%. At first thought this is somewhat surprising because of the greater volume of flame. The saving, however, is due to the efficient manner in which these flames are applied to the work. With multi-flame tips it is desirable to use a narrower included angle or bevel in the weld groove. An included angle of 50°, or even 45°, is used for ordinary run of line pipe. (No bevel is needed on smaller sizes and lighter weight pipe.) On virtually all sizes a single pass is sufficient to complete the weld.

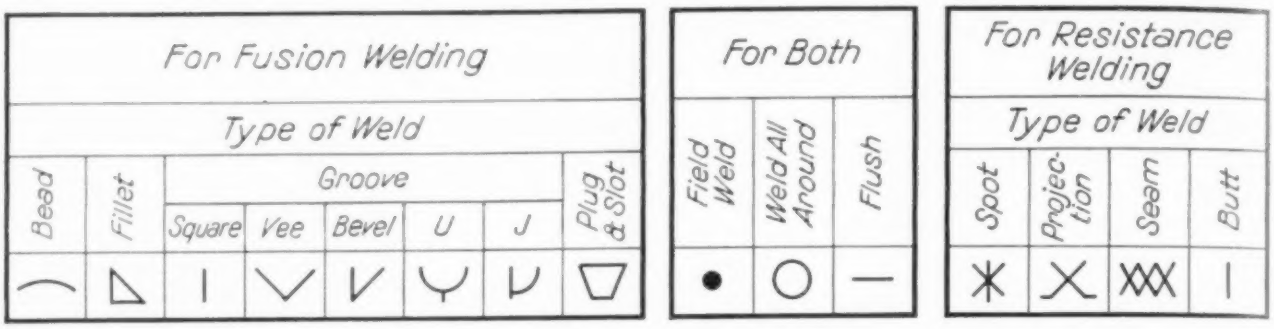
Since the heat is more uniformly concentrated immediately adjacent to the puddle and the operation is much faster, the result is a more uniform heating at the weld with more rapid dissipation of the welding heat. The net result is a narrower heat band with a minimum of normalizing and no embrittlement.

No small part of the success of this type of welding is due to a low alloy, high strength steel welding rod especially developed to insure uniformly high quality welds in high strength pipe. Weld metal from this rod sets up much more rapidly, thereby making it easier to control the puddle, prevent icicles and "running", and resulting in greater welding speed. In application the molten end of the rod is in the welding flame and the section immediately above it is in the preheat flame. This insures a minimum of oxidation and gas inclusions and results in a better and more uniform joint.

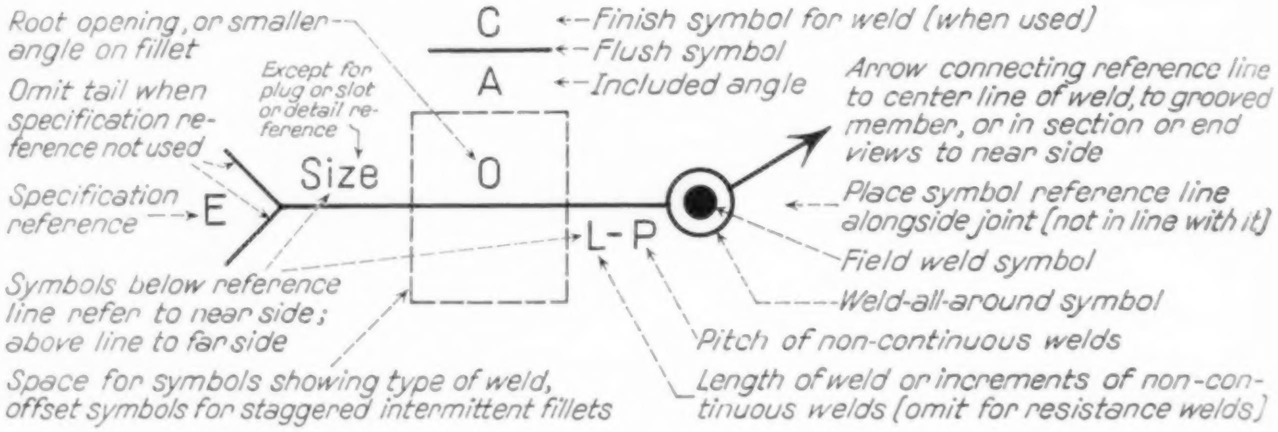
The use of this tip goes far toward minimizing the chance for human error. With the blowpipe held in proper position relative to the vee and the rod, the proper amount of heat is automatically applied to the vee, the weld, and the rod. Movement of rod and blowpipe is

Welding Symbols

Adopted as Standard by American Welding Society, 1937



Standard Location of Information on Welding Symbols



Significance of Typical Combinations

For other combinations see "Welding Journal", June 1937

confined to a back-and-forth or accordion motion along the line of the weld. The flame is adjusted in the same manner as for a single-hole or three-hole tip.

Experimental developments with this multi-flame tip are in some instances so startling as to lead one to predict a revolutionary change in the technique of oxy-acetylene welding.

Flame Cutting

By George V. Slottman
Asst. Manager, Applied Engineering Dept.
Air Reduction Sales Co., New York

PERHAPS the most significant development in what was formerly termed the "art of oxy-acetylene cutting" is its rapid transition into a technical science. Demand for quality and economy in the cutting of parts for mass production of fabricated shapes has impelled production engineers to study the factors involved, and to establish shop controls to realize the ultimate economies inherent in the process. Control of cutting speed, of tip size, and of oxygen and acetylene pressures for the various thicknesses of steel and qualities of cut surface is now being recognized as essential to good management of a cutting department.

Use of machine propelled torches when cutting shapes for fabrication by welding is very extensive. The past year has seen an active development in oxy-acetylene cutting machines as regards size, cutting areas, and adaptability to specific applications. The range has been extended so that there are now available machines which can cut 10-ft. widths in unlimited lengths. Other machines are little more than motorized hand torches and are so priced that no one having quality cutting to do can afford to be without them.

A number of special machines has been developed for the mass production cutting of risers and round bar stock. The foundryman desires to cut risers to the line (to eliminate grinding) and while this development has been slow, there is sufficient interest to indicate that the oxy-acetylene cutting machine will soon take its place on the production line of the steel foundry now occupied by the hand torch.

Further evidence of the technical interest in the process is shown by the number of investigations made on the effects of flame cutting on steels, in the effort to extend the range of the process to alloys that formerly were cut with difficulty, such as the stainless steels, or that suffered impairment of their physicals, such as the higher carbon and high tensile steels. Moderate preheating of the entire part has permitted locomotive frames to be cut from a single rolled slab of high tensile steel. Preheating of the cut path immediately before or after the cutting jet has allowed the high tensile steels to be cut in thinner sections without loss in impact resistance. The urge to cut to the line and to eliminate subsequent machining operations has given rise to much study of the cutting technique, and the future will show many applications resulting from such investigations.

Much thought is being given to the subject of flame machining, that is, of using the oxy-acetylene cutting torch as a planer for rough machining or hogging-out. This application has been generally adopted by the steel industry for the removal of defects in steel bars or billets prior to finish rolling, and by foundries for removing casting defects. In the steel industry, oxygen de-seaming has revolutionized the operation of steel conditioning and machines have been developed to the point where all four sides of a 14-in. bloom can be surfaced simultaneously at linear speeds of 100 ft. per min. The extension of this use to industry at large for scarfing out defects in welds or for removing the bottom bead of a weld, for preparing welding U's and for rough machining operations in general, will undoubtedly be one of the significant developments of the near future.

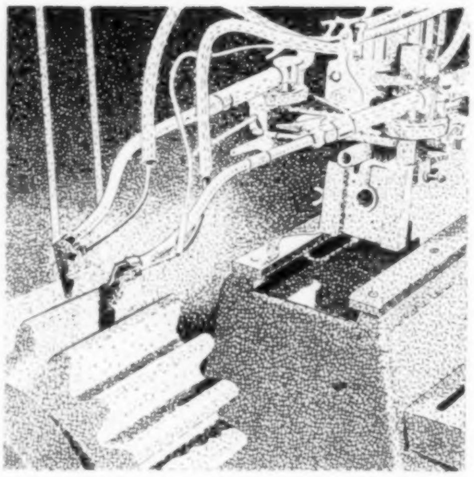
Silver Brazing Alloys

By Robert H. Leach
Vice-President, Handy & Harman
Bridgeport, Conn.

CONSIDERABLE PROGRESS has been made during the past year in developing new applications for brazing alloys containing silver, commonly called silver solders. The term "brazing alloys" is used in the heading because our observations indicate that many potential users think that "solder" and "soldered joints" mean a type of alloy and joint made with the lead-tin solders; whereas silver solders are hard alloys and silver soldered joints have high strength and ductility and resistance to shocks, vibration, and corrosion.

As engineers and designers of equipment have become better acquainted with these alloys and particularly with their free-flowing properties at temperatures much lower than those required for brazing alloys containing only base

metals, they have been able to provide strong and leakproof joints without danger of overheating the metals or alloys to be joined. Moreover, the hesitancy to use silver brazing alloys because of their supposed high cost is rapidly disappearing because closely fitted joints give best results and only a comparatively small amount of the alloy is required.



A large amount of educational work on the properties of the silver brazing alloys and the procedure to follow in the proper use of them has been carried out in different industries. This work has resulted in not only greatly improved products but economies in production over other methods of joining.

Although their low melting points make them particularly desirable for joining copper, brass, bronze, monel metal and other non-ferrous alloys, they are used extensively with ferrous metals, including stainless steel. Their use is not limited to joining small parts but includes such products as hot water boilers, tanks, and large pipes and fittings. An interesting example is in the construction of a water tube boiler where 1238 copper tubes, 35½ in. long, ¾ in. outside diameter, 0.049 in. wall thickness, were joined to two mild steel headers ¾ in. thick and 48 in. in diameter by means of a silver brazing alloy with a flow point of 1175° F. This boiler has given satisfactory results in service and is operated at 225 psi. pressure, the temperature of the steam being 396° F.

The alloys can be obtained in wire, sheet, filings, or powder of the size most suitable for any particular job. In those cases where a light pressure can be applied, the use of inserts a few thousandths of an inch thick between the surfaces to be joined produces sound, strong joints. Where pressure cannot be applied, as in joining pipes and fittings, a very satisfactory method of completely filling the joint has been developed which consists of cutting a groove in the fitting into which a ring of the brazing alloy is placed before inserting the pipe.

Improvements in methods of heating the joints have contributed to the more extensive use of these alloys, as better control of temperature utilizes their low melting points to the greatest advantage. Heating with different types of torches continues to be the favorite method, and improvements in their design and the use of multiple tips have produced quicker and more uniform heating. Furnaces, both gas and electric, with automatic control of temperature, are being used to good advantage with these alloys. Salt bath furnaces also allow close control of temperature and this method of heating gives promise of increasing use. When brazing in a furnace the parts must be assembled with the silver brazing alloy either along or in the joint, and properly jigged to hold the parts in place during heating. Electric resistance brazing methods have been developed which give excellent results because of the localized heating and short time required. Heating by induction has also been applied to special jobs.

With the new uses that are constantly being found, it seems reasonable to expect that the resumption of business activities will require much larger quantities of these alloys.

Flame Hardening and Softening

By Roger B. White
Service Engineer, The Linde Air Products Co.
Cleveland

EVEN though the terms flame hardening and flame softening are becoming well known, a brief account of the two operations may not be amiss.

Flame hardening produces a hard surface on steel or cast iron parts by a short sharp heat, usually from an oxy-acetylene flame, followed by a quenching spray. In parts of considerable mass it is proper to select the composition and preliminary heat treatment (usually a normalizing heat) so that the bulk of the article will have the required strength and toughness and the flame then hardens the desired surface.

Depth and degree of hardness obtained are controllable over a wide range, varying from $\frac{1}{16}$ in. to ⅜ in. and from 300 Brinell up to very near the maximum obtainable on the material used. From the very nature of the process it

is carried out quickly and does not require complicated equipment of difficult handling. The portability of the equipment is of great importance, especially in hardening vulnerable areas on large objects.

Distortion, which is so frequently troublesome on furnace hardening jobs, is generally negligible with flame hardening because heating and quenching is confined to such a small portion of the entire piece.

Materials suitable for flame hardening include a wide range of carbon and alloy steels and cast irons. Plain carbon steels from 0.35 to 0.70% carbon are suitable for this treatment. Detailed discussion of the response of different materials to this process and of the mechanics of the operation is omitted here because much of this information has been published.

Flame softening has not been in the limelight but is receiving more attention daily. As the name implies it obtains opposite results with the same means. All that is necessary is to regulate the heat input and omit the quench so as to cool the material through the critical range at a rate too slow for effective hardening — that is, provide a normalize or annealing cool rather than a quench hardening cool.

This process is used to remove undesired surface hardness produced by chilling or cold working such as may result from electric welding, flame cutting high carbon or low alloy steels, shearing or cold bending.

Of unusual interest is the softening of flame cut steels, appropriate to analyses containing over 0.35% carbon or steels with low alloy additions. The cut surface will be found definitely harder than the base metal and in the more hardenable steels serious embrittlement may be found. The undesirable hardness results from the rapid quench of the heated metal alongside the kerf by conduction to the cold metal behind it. This hardening may be objectionable for two reasons, (1) difficulty of machining, (2) susceptibility to subsequent cracking.

Softening of flame cut steel can be effected by several methods: (1) Heat treating simultaneously with cutting by means of banks of flames mounted on the same machine which propels the cutting blowpipe (heating ahead of the cutting blowpipe to reduce the rate of cooling, or post heating to anneal the surface); (2) heat treating after cutting and opening up the kerf by applying banks of flames directly to the cut surfaces.

At present the use of these flame treating processes is expanding very rapidly. This rapid growth is occurring in the face of considerable development expense, and this is conclusive evidence of the substantial savings to be anticipated. Today, however, enough is known about flame treating to make expensive development work unnecessary for most new applications. Predicted results are being obtained on such new applications daily.

Resistance Welding

By C. E. Seifert
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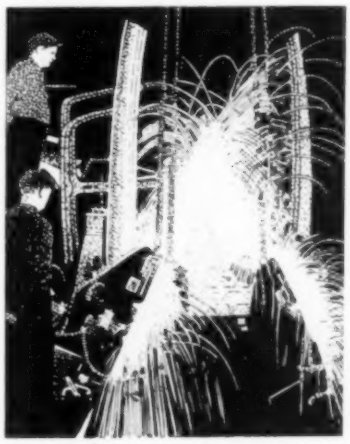
During the past few years, and probably for the immediate future at least, the tendency seems to be to install larger and larger resistance welding machines of all types and classes, that is, spot, press, butt, seam or flash welders. While a large number of more-or-less standardized machines are being sold, there is another tendency toward "custom built" equipment, adapted to particular operations on definite steels or alloys — in other words, the trend is toward designing and developing that type of machine which will work best in production.

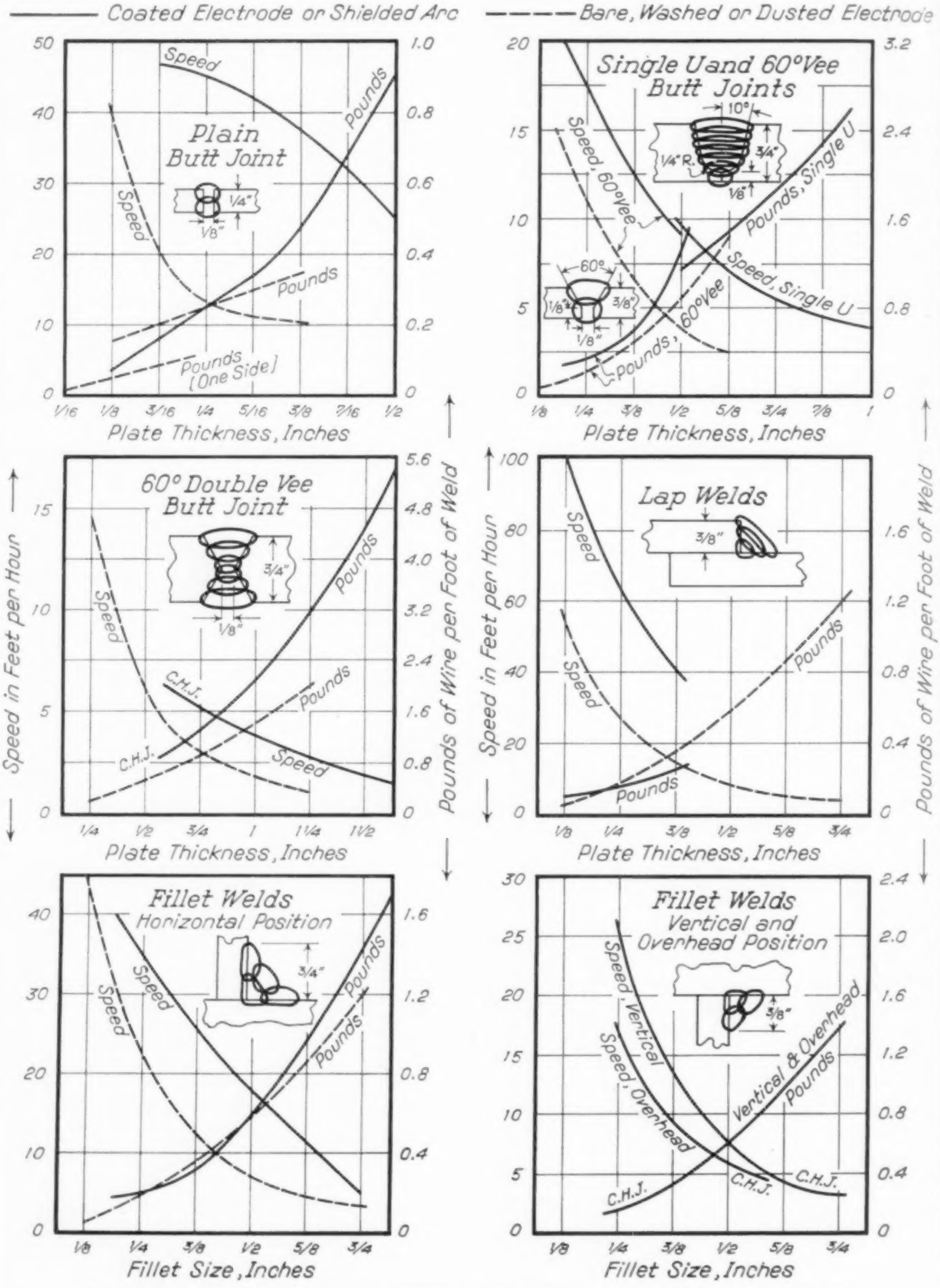


Butt and flash welding of sheet steel is no new thing — witness the universal construction of automobile bodies by this method. An important extension of the process is to strip and various coiled material. Since production operations are facilitated by automatically feeding a long coil into one or a battery of machines, it follows that additional economies would be effected by joining the tail end of one coil to the front end of the next without interrupting the main production line — in effect, providing endless coils.

In spot welding applications in particular, there has been a great tendency toward the use of multiple welding machines, incorporating any number of welding points operated by hydraulic cylinders in rapid succession or together according to the requirements of the

Speed of Manual Arc Welding

In down position and 100% operation factor. Discount speeds according to efficiency of shop management up to 50% for piece work and 67% for day work



Data from "Procedure Handbook of Arc Welding", Lincoln Electric Co., except curves marked C.H.J. from "How to Weld 29 Metals" by Charles H. Jennings, Westinghouse Elec. & Mfg. Co.

job. Such machines are quite likely to have anywhere from four or five welding heads to even several hundred welding electrodes and a multiplicity of transformers in order that several welds may be made at a time instead of singly.

The development of control apparatus such as timers for controlling ordinary contactors and the development of the thyratron and ignitron controls have materially speeded up production welding operations and have, in many cases, reduced the cost of maintenance of the machine. This is especially true of the ignitron and thyratron controls (using electronic devices) which make and break the welding circuit many, many times a minute if necessary without the use of any moving parts. In the larger installations of heavy electrical capacity, there will undoubtedly be more and more use of these electron tube controls in preference to the ordinary magnetic contactors previously available. Exceedingly close control of current — even to a selection of the correct portion of the "sine-wave" — is of great advantage in the spot welding of such dissimilar things as the strong aluminum alloys or stainless steel (where the amount of heat is critical) or heavy steel plate (where interrupted currents of definite on-and-off program are desirable).

Hard Facing Overlays

By Don Llewellyn
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Los Angeles, Calif.

HARD FACING as a welded-on overlay or application has been used scarcely more than ten years. However, thousands of applications have been developed and economically introduced in almost every industry.

Hard facing materials are metallurgically in a family by themselves, since the metals have properties or characteristics unlike those with which we are more familiar. Most of them appear to be of an austenitic or solid solution structure, although they are in the higher hardness range with extremely high abrasive resisting qualities even at elevated temperatures, and are not affected by heat treatment. Possibly the high hardness and abrasion resistance of some of them is due to a spontaneous hardening (change to martensite) during the first slight deformation. In others the hardness is probably inherent, and the crystallographer would say is due to a very complex or irregular space lattice. Still others might be called "artificial diamonds", they being carbides, borides or other compounds of certain metallic elements, having exceedingly great intrinsic hardness.

Hard or austenitic alloys may be welded on to ordinary steels. Hard particles are "set" in a softer metallic binder, as it is welded on.

Manufacturers have found it necessary to produce many types of materials in order to meet the various conditions under which a machine part, carrying the overlay, works. In some cases the overlay would be called upon to withstand heavy impact or shock. Others must work in acid or corrosive surroundings. Still others must resist abrasion while working under elevated temperatures.

When the proper material is selected and welded on the vulnerable areas, one can expect an increase of from three to ten times in the life of the machine part, thus eliminating replacements, shut downs, and many other items of expense in the maintenance of the whole machine. If the part is a cam, stop or guide, where accurate adjustments must be kept, the over-all efficiency of the machine is also increased to an appreciable degree.

Designers of new equipment have also incorporated the composite overlay on the vulnerable areas of new parts, wherever serious erosion is contemplated. For instance, all oil well drilling bits are hard faced today as they are being manufactured. No oil company would think of running a drilling bit into the hole unless it had first been hard faced with the best material obtainable. (Ten years ago the hard facing of oil well drilling bits was still in its experimental stages.)

Hard facing materials are simple to use because they are readily weldable to ordinary cast iron, steel, or steel alloys which make up the majority of the machine parts. The vulnerable areas of the part are ground away, and a small amount of the hard facing material is welded on, and the part then ground to size.

Hard facing has proven to have so many advantages in the maintenance of equipment in our industrial plants that we have every reason to believe that its usefulness has scarcely been suggested. One application now generally used is the valve inserts of your automobile; another is seats for high pressure steam valves. The valve inserts of your automobile are commonly known today, as thousands of other applications will be commonly known and used with practical and economical results in the future.

Clad Metals

By Louis J. Larson
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A BI-METAL (or better, a clad metal) consists of two metals having different properties and characteristics bonded together to act as a unit. The purpose is to obtain some of the desirable properties of both without the undesirable qualities of either.

"Bi-metals" is frequently used for combinations of precious or semi-rare metals used by jewelers or instrument makers. "Clad metals" may therefore be applied to that rather large tonnage produced in the form of sheets and plates and used in the fabrication of equipment subjected to corrosion. Such material, often called "clad steel", is made up of carbon steel or one of the relatively inexpensive low alloy steels, with a layer of high alloy usually on one or sometimes on both sides.

Clad metals and bi-metals are manufactured by a number of processes of which the following are the most important:

1. One of the metals is poured around or against the face of the other metal (often preheated) and the composite ingot is hot rolled to size.

2. Plates or slabs of the two metals are placed together in a furnace, heated to welding temperature, and the weld obtained in a press or during hot rolling. Rolling to gage may then be hot or cold.

3. The alloy is fused or deposited on the steel plate with a metallic or carbon arc and the composite slab is hot rolled to finished size and the proper surface. The amount of hot rolling in this process need not be great because the joint is accomplished by the arc.

4. Sheets of alloy are attached to steel plates by arc welding through perforations in the sheets, or by fusing through the sheets. In this case there is no bond on the areas between the arc welds.

5. Sheets of alloy are spot welded on close centers to steel plates. Although this results in fusion only at the spot welds, the strength of the bond is sufficient for fabrication operations and service conditions.

Unless proper precautions are taken in the first two processes the formation of oxides on the surfaces of the alloy may interfere with proper fusion and result in loose areas. To facilitate the bonding the alloy parts are sometimes plated with electrolytic iron before furnacing. In the non-ferrous alloys a thin sheet of silver solder may be inserted.

When the bond is obtained by arc welding special precautions are necessary to prevent cracks in the areas of the welds if the alloy is self hardening.

The percentage of alloy in a bi-metal depends upon the service requirements and upon the method of production. Clad steels made by the first two processes, in which there is a large reduction in thickness by hot rolling, generally have from 10 to 20% of alloy, and 90 to 80% of steel backing. When sheets of alloy are used with no subsequent reduction in thickness the percentage may be as low as 2% for attachment by spot welding.

All five processes have been used for the manufacture of some of the stainless clad steels. Welding by hot rolling is used for cladding with nickel and Inconel. The spot welding process has been used for all the usual types of stainless (both ferritic and austenitic types), for Inconel, Monel, nickel and Hastelloy.

In addition to the clad metals mentioned above which have been used commercially in the form of plates, steels clad with silver, copper and some bronzes have been produced, generally by the casting process. Bi-metals for the jewelry and instrument trade are too numerous to list; well-known examples are "Sheffield plate" (silver over copper) and thermostatic metal (brass and steel).

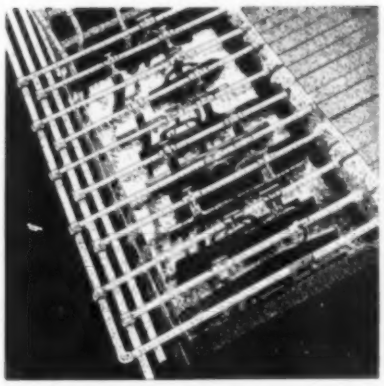
In fabricating equipment of clad metal, welding of the joints in the alloy presents problems but the developments in welding have kept pace with the production of the materials. For welding the ferrous alloys it is generally possible to use rods having a high enough alloy content to compensate for the dilution due to fusing onto the carbon steel. To eliminate excessive iron content in the exposed surface at the joints multi-layer deposits, alloy inserts or cover straps of alloy may also be used.

Clad metals have found numerous applications in the petroleum, paper, chemical, and allied industries. The use of an inexpensive steel to carry the loads with only enough alloy to furnish the corrosion resistance offers the possibility of large savings provided the cost of manufacturing the clad metal plate does not offset the savings in cost of the materials. Manufacture of large, corrosion resistant vessels, requiring thick plates, demands their use not only because the cost of solid alloy would be prohibitive but also because the technique of fabricating and welding heavy sections has not been developed for many of the high alloys. An increasing use of clad metal may be therefore expected as the cost is reduced.

NON-FERROUS METALS

METAL PROGRESS

OCTOBER 1938



Non-Ferrous Metals

Powder Metallurgy

By Gregory J. Comstock
Manager, Metal Powder Products Division
Handy and Harman, Bridgeport, Conn.

A RECENT CANVASS of the principal manufacturers of metal powder products indicates that their efforts recently have been primarily directed toward refinements of existing processes and improvements of current products. Development of new products is of course being continued, but the pace has been modified by general business conditions.

Commercial application of powder metallurgy is therefore still principally confined to the quantity production of various forms of the refractory metals, tungsten, molybdenum and tantalum; porous bearings; contact materials; and hard cemented carbides. Numerous other applications are known to be nearing the stage of industrial production. It is interesting to observe that new commercial developments are apparently being directed toward one general class or type.

All powder products can be quite definitely classified into two types. Those that are cemented by the action of a binder which is molten at one stage of their fabrication may be considered as being of one type. Those that are consolidated from powder by the bonding of their metallic particles *without* the formation of any quantity of a liquid may, for purposes of general classification, be considered as another type. The hard cemented carbide tool materials are an example of the first type; the strong but pliable tungsten wire or filament is a familiar example of the second.

The formation of a liquid cementing medium is a more or less positive action. Its results are quite clearly discernible in the final product. Its effects are largely understandable even in the light of our present knowledge and can, therefore, to a certain extent be anticipated and intelligently discussed. If the liquid which is formed alloys with the major unmelted component, or has a tendency to dissolve it even slightly, it fulfills the requirements for capillary action and is distributed in its molten state by that agency throughout the mass of the undissolved powder particles.

Two strongly limiting conditions, however, must be recognized as affecting this method of metal powder fabrication: *(a)* The liquid which is formed must be in distinctly minor proportions, or nothing but a badly segregated melt results; *(b)* particle size must be carefully regulated or the liquid becomes saturated too soon by dissolving the easily assimilated smaller particles. It is then no longer able to fulfill the requirements that were previously responsible for its complete distribution and bonding action, and low strength unsatisfactory materials result.

The first mentioned type of powder products requiring the formation of a liquid binder must therefore be limited to materials that can satisfactorily consist of a large preponderance of a very carefully sized component. Powder aggregates display the characteristics of their components in almost exact proportions to their presence in the composition. Products of this type must therefore resemble the major component which is required to be present. If it is hard, the final materials are also hard; if it has a tendency to brittleness, so of necessity has the product made with a liquid binder.

Bonding the adjacent powder particles *without* the formation of a self distributing molten binder is by no means as positive an action as the one that occurs when this liquid cementing medium is formed. The very nature

Copper and Its Alloys in Wrought Form

Prepared by M. G. Steele, Technical Adviser, Revere Copper and Brass, Inc.

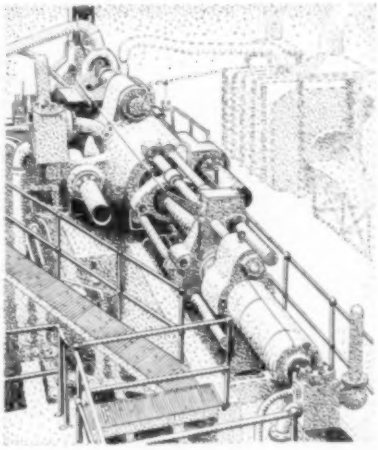
Metal	Type Composition: Cu	Zn	Pb	Sn	Ni	Properties (Hard & Soft): Tensile Strength	Elongation	Elastic Limit	Forms	Properties and Uses	Methods of Working
Copper (electrolytic)	99.9					51,000 32,500	4 47	48,000 12,000	Sheet; Bar; Tube; Rod; Plate	Corrosion resistance; ductility; high conductivity. Roofing; bus bar; high conductivity tubing	Stamp; Draw; Weld; Solder; Forge; Form
Copper (lake)	99.9	7 oz. silver per ton				51,000 32,000	4 47	48,000 12,000	Sheet; Strip; Rod	High annealing point. Auto radiator fins; lock seam tubing	Stamp; Draw; Solder; Form
Copper (phosphorized)	99.9	0.04 phosphorus max.				55,000 35,000	5 45	44,000 16,000	Sheet; Strip; Tube	Draws and coils better than electrolytic. Water, refrigerator and oil-burner tubing	Stamp; Draw; Forge
Copper (arsenical)	99.9	0.04 phosphorus 0.30 arsenic				60,000 36,000	4 40	55,000 7,000	Sheet; Tube; Plate	High strength; resists heat and flaking. Condenser tubes	Stamp; Draw; Forge
Copper (cadmium)	99	1.00 cadmium				80,000 35,000	4 45	68,000	Rod	High strength. High strength parts; trolley wire	Draw; Forge
Copper (beryllium)	98	2.00 beryllium				175,000 75,000	6 45	134,000 31,000	Sheet; Tube; Rod	Very high strength; hardness; high conductivity. Springs; cutting tools	Stamp; Draw; Forge; Form
Brasses											
Gilding metal	95	5				55,000 35,000	5 38	39,000 11,000	Sheet; Strip; Tube	Ductility; reddish gold color. Primers; detonator fuse caps; jewelry; forgings	Stamp; Draw; Forge; Form
Commercial bronze	90	10				67,000 37,000	3 40	53,000 11,000	Sheet; Strip; Tube	Ductility. Used for color match; stamped hardware; bullet jackets; jewelry; caskets; screen cloth	Stamp; Draw; Forge; Form; Perforate
Rich low brass	85	15				75,000 42,000	4 43	52,000 15,000	Sheet; Strip; Tube	Corrosion resistance. Brass pipe; jewelry; badges; name plates; etchings; tags; dials	Stamp; Form; Draw; Blank; Etch; Weld
Low brass	80	20				85,000 43,000	4 50	65,000 15,000	Sheet; Strip; Tube	Corrosion resistance; yellow color. Jewelry (for gold plating); fulton bellows.	Stamp; Form; Draw; Spin
Seventy-thirty or cartridge brass	70	30				86,000 45,000	4 50	65,000 15,000	Sheet; Strip Tube	High ductility; deep drawing. Pins; rivets; eyelets; radiators; cartridge shells; spun articles	Stamp; Spin; Deep Drawing
High brass	66	34				90,000 48,000	4 50	70,000 15,000	Sheet; Strip	High ductility; deep drawing. Brass pipe; auto reflectors; stampings; radiator fins	Stamp; Spin; Deep Drawing
Leaded high brass	65	33.5	1.5			80,000 45,000	5 60	60,000 15,000	Sheet; Strip	Forming by bending; free machining. Engravers' brass; lighting fixtures; clock and watch backs; gears; keys	Stamp; Form; Bend; Punch
Free cutting rod	62	35	3			62,000 47,000	20 60	25,000 15,000	Rod	Typical brass rod; free machining. Extruded shapes; screw machine parts	Machine; Thread; Extrude
Forging rod	60	38	2			70,000 50,000	10 45	31,000 15,000	Rod	Hot forgings; faucet handles; shower heads	Forge; Extrude; Machine;
Muntz metal	60	40				80,000 57,000	9.5 48	60,000 15,000	Sheet; Plate; Tubes	Condenser tubes and heads; ship sheathing; perforated metal; brazing rod	Draw; Punch; Forge
Architectural bronze	56	41.25	2.75			70,000 50,000	10 20	55,000 15,000	Sheet; Strip	Strength; hardness; free cutting. Extruded shapes; forgings; interior ornamental bronze	Extrude; Forge; Machine
Special Brasses											
Silicon brass	78	20	2.0 silicon			110,000 55,000	4 61	83,000 12,500	Sheet; Strip	High strength; weldability. Refrigerator evaporators; fire extinguisher shells	Resistance Weld; Stamp; Draw
Aluminum brass	76	22	2.0 aluminum			83,000 62,000	17 52	75,000 16,000	Tube	Resistance to corrosion and erosion; self healing skin. Condenser tubes	Draw; Extrude
Admiralty	71	28		1		95,000 45,000	5 60	92,000 18,000	Sheet; Strip; Tube	Resistance to corrosion, especially of sea water. Condenser tubes	Stamp; Draw; Extrude
Naval brass	60	39.25		0.75		75,000 54,000	15 45	39,000 15,000	Sheet; Rod; Tube	Resistance to corrosion in sea water. Tube heads; marine shafting; bolts; forged parts; window anchors	Draw; Forge
Bronzes											
Phosphor bronze	98.75	0.05 phosphorus		1.2		65,000 40,000	4 48	50,000 15,000	Sheet; Strip	Resilience; strength; hardness; corrosion resistance. Springs; bearings; small parts	Stamp; Form; Weld
Phosphor bronze	92	0.05 phosphorus		8		110,000 55,000	3 55	85,000 25,000	Sheet; Strip; Rod	Similar to above. Welding rod	Stamp; Form; Weld
Silicon bronze	96.25	3.25 silicon		0.50		110,000 60,000	5 55	100,000 25,000	Sheet; Tube; Rod	Strength; weldability; corrosion resistance. Tanks; bolts; screws; lags; chain; locomotive hub liners; welding rod.	Stamp; Draw; Forge; Weld; Extrude; Cast
Aluminum bronze	95	5.0 aluminum				105,000 57,000	5 55	80,000 24,000	Sheet; Tube; Rod	Corrosion resistance; strength; golden color. Condenser tubes; gift articles	Stamp; Extrude; Draw
Manganese bronze	59	39	1.25 Fe.	0.75	0.05 Mn	75,000 60,000	5 35	50,000 15,000	Sheet; Strip; Rod	Resistance to wear and corrosion. Welding rod; perforated coal screens; extruded wearing parts	Extrude; Perforate; Weld
Nickel-Silvers											
Nickel silver (typical)	65	20			15	93,000 58,000	5.5 45	75,000 15,000	Sheet; Strip; Rod	Resistance to corrosion; strength. Extruded shapes; table silver; instruments; key stock; springs	Forge; Extrude; Stamp
Cupro-Nickels											
Cupro-nickel (eighty-twenty)	80				20	80,000 49,000	3 42	78,000 17,000	Tube	Resistance to corrosion, erosion, heat and chemical attack. Condenser tubes	
Cupro-nickel (seventy-thirty)	70				30	84,000 49,000	4 50	83,000 18,300	Tube	Same as above but more resistant to corrosion. Condenser tubes	
Cupro-nickel (zinc alloy)	75	5			20	85,000 50,000	5 35	77,000 23,000	Sheet; Tube; Rod	Same as 80-20 above but less resistant to corrosion. Condenser tubes	

of the bonds formed by cementing without actual fusion is not fully understood nor is their exact character discernible by observation of the final product.

Two very favorable conditions affect this method of metal powder fabrication, however, and are responsible for the present general trend to develop experimental powder products of this type in preference to the other: (1) Compositions of this type do not of necessity require the presence of a major proportion of any single component; their physical characteristics may therefore be varied widely in comparison to those that must consist of a preponderance of one material. (2) Within limits, an affinity between the components is apparently not essential.

These factors present an attractive opportunity for the development of materials which may reasonably be expected in time to cover a wide field of useful applications. Encouragement is afforded by the strength of the particle-to-particle adhesions which can be produced under optimum conditions, and the unusual combinations of metals or non-metals which can be made by it. Bonds of tremendous strength are demonstrably obtained by "diffusion-welding" in the production of tungsten wire. Extremely ductile combinations of non-alloying metals displaying 40 or 50% elongation can be produced if the bonding by this means is properly accomplished. Hard particles can be included in strong, hard, thermally stable matrixes in which they are bonded without the composition limitations which are unavoidably involved in the formation of liquid binders.

Experience is being acquired as to the technique and equipment which is best suited for developing and manufacturing a variety of specific materials of this general type. Research is being conducted into the fundamentals of this kind of bonding and the conditions that must prevail for its most satisfactory accomplishment. It is felt that the present trend toward the development of metal powder products fabricated by these means is a logical one, and that it will be eminently justified by results.



Developments in Copper Alloys

By D. K. Crampton
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A REVIEW of all the copper alloy developments in the space available would of necessity limit this contribution to little more than a listing of topics. It therefore seems preferable to select a relatively few of the more interesting items and treat these in slightly greater detail.

Of great technical interest and potential commercial importance is the newer technique of producing thin, highly resistant surface films on copper and its alloys. With suitable heat treatment and carefully controlled atmosphere, the composition of the oxide film is controlled. These films appear remarkably effective in preventing or delaying atmospheric tarnish and may even be valuable in combating certain types of aqueous corrosion.

Additional age hardening alloys (copper-base) are now finding commercial application. For instance, considerable quantities of copper-chromium and copper-zirconium alloys have found application for resistance welding electrodes. For such uses these have desirable combinations of mechanical, electrical and thermal properties not exhibited by the ordinary solid solution copper alloys.

Another promising application is that of the copper-nickel-aluminum alloy (age hardening) for bolts, especially large hot headed ones. Here the ability to obtain a very high strength and hardness by heat treatment after hot heading, together with exceptionally high resistance to corrosion and stress corrosion, make it very well suited to the required duty.

The time-honored practice of pickling all copper alloys in sulphuric acid solutions has been found inadequate for some alloys which form refractory scales on annealing. Some progress is being made on the use of new pickling solutions of oxidizing acids which perform better, faster and more economically.

The problem of obtaining clean, bright surfaces has also been effectively attacked from an entirely different standpoint. Believing that prevention is better than cure, several

investigators have made great improvements in bright annealing technique. Even the high zinc brasses and alloys containing such troublesome elements as silicon, probably can now be successfully handled. The solution to the problem appears to be in precise control of time, temperature, and all factors entering into furnace atmosphere.

The welding of copper and its alloys has received much study. Copper itself, both tough pitch and oxygen free, is being satisfactorily welded by the carbon arc process. This same procedure is now being used commercially to give weld strength in silicon bronzes consistently above 50,000 psi. Spot welding and stitch welding of copper alloys are being developed steadily. In addition to silicon bronzes, which have been so welded for several years, silicon brasses and even straight brasses are now satisfactorily welded by resistance processes.

Of interest to fabricators of brass is the increased availability of long coils of strip. Heretofore most copper alloys in strip form have been made from bars cast in a form and size for cold rolling and for convenient manual handling in the mill. Now several procedures calculated to give much longer coils are being increasingly used. They include hot rolling from heavier cakes, extruding of flat strip and subsequent cold rolling, continuous strip-casting, and welding or resistance brazing of two or more ordinary coils.

Mill Methods for Tubes

By R. A. Wilkins
Vice-President (Research and Development)
Revere Copper & Brass, Inc., Rome, N. Y.

DEVELOPMENTS in non-ferrous tube mills over the last few years can be conveniently discussed under two different headings: Alloy development and equipment development.

In the first place, there has been a distinct change in the manufacture of condenser and engineering tubes. Until comparatively recently admiralty metal tubes were more or less standard for condenser purposes. Within the last few years, however, the introduction of the English "aluminum brass" tubes in this country has directed attention to the virtues of this particular product and they are today standard with the brass mills engaged in the manufacture of condenser tubes.

The British Admiralty practice and the requirements of our own Navy have also emphasized the importance of cupro-nickel as a tube alloy where the duty is severe and dependability and performance are essential.

The production of cupro-nickel, aluminum brass and other special alloys of a so-called refractory rather than malleable nature has, with other considerations, influenced the trend of development insofar as equipment is concerned. Thus, over the last few years brass mills, particularly those engaged in the manufacture of these refractory alloy tubes, have gone almost exclusively to extrusion as a basic operating procedure.

On the refractory alloys and to some extent on the more malleable materials the so-called tube reducing process has found considerable application in preference to the drawbench. In this type of equipment the extruded shell is placed over a tapered mandrel and the wall thickness and diameters are reduced by the action of reciprocating, taper-grooved rolls.

Both on condenser tubes and on standard copper and brass, controlled atmosphere annealing in either gas or electric-fired furnaces has been widely introduced following the same trend observed in the annealing of strip and sheet materials.

As would be expected, the introduction of alloys of the cupro-nickel type and the introduction of aluminum brasses into the tube mill has necessitated a general development and improvement in die steels both for extrusion and for drawing. In addition, some little application has been made of abrasive cut-off disks in place of saws for the tougher and more refractory alloys.

Sand Cast Alloys and Foundry Methods

By Harold J. Roast
Vice-President, Canadian Bronze Co., Ltd.
Montreal, Canada

AS I LOOK over the situation of the non-ferrous sand cast alloys, I find that two bronzes, with which I am personally acquainted, have made considerable progress in the last year in the engineering field. One is known as "Everdur" and the other is "P.M.G.", the former being made by the American Brass Co. and the

latter by the Phelps Dodge Corp. in the States and by Canadian Bronze Co., Ltd. in Canada. These bronzes have shown particular resistance to cavitation and, in my experience, foundries using the alloy find that it is an easy one to handle. The beryllium bronze has also made progress for special work.

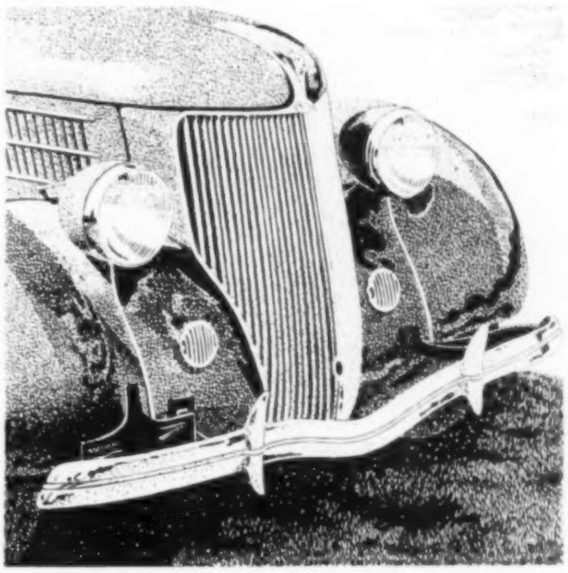
Thinking of these bronzes, one is reminded of the fact that heat treatment of non-ferrous alloys is becoming more and more common. A few years ago, this practice was practically unknown. Silicon bronze has been modified to permit of heat treatment, beryllium bronze always depended upon heat treatment for its best results, and aluminum bronzes, which have been heat treated for some time, are now being so used to a much larger extent.

Sand is necessary for making sand cast alloys. One of the great improvements in sand has been the use of synthetic sand, but this has not proved satisfactory where the finer sands corresponding to what is called "No. 1 Albany," or sands of a grain fineness of 200 plus on the American Foundrymen's Association scale, are required. It is in just this class of sand that a great deal of non-ferrous molding falls. It is, therefore, not possible to make much if any use of the synthetic method of approach. I notice, however, as each year goes on, more sand suppliers and purchasers are adopting scientific methods of classification.

There is also a great increase in the information provided for the foundry superintendent through such avenues as the frequent meetings of technical societies and regular issues of scientific and trade journals. Years ago, the foundryman got only such information as was passed from mouth to mouth, which in itself was based on rule of thumb method. Nowadays, the foundryman can, if he will take the trouble to inform himself, have the benefit of the latest in practical and scientific research.

Various state and federal requirements in connection with manufacturing hygiene are calling for improved working conditions in non-ferrous as well as other foundries. Systematic medical examination, proper facilities for showers, the supply of fresh heated air during the winter months, all these things have been used to an increasing extent in the past year. The very latest "electrostatic precipitron" of the Mines Safety Appliances Co. shows the continued advance that is being made in the estimation of the lead content of a foundry atmosphere. Prior to this apparatus, the impinger method of collection had an effectiveness of something like 30 to 50%, passing most of the finer particles, whereas the new method has practically 100% efficiency.

I notice that competition with welded structures and other metals, such as stainless steel, duriron, and other corrosion resistant materials, is causing the foundry to place a higher standard on what is called a "good" casting. The metal must be sound upon fracture as well as by outside appearance. This is an important step in the right direction, for only honestly good castings — that is, non-ferrous castings good all the way through — can hope to compete successfully with units made up of welded wrought products, sheet and tubing.



Die Castings

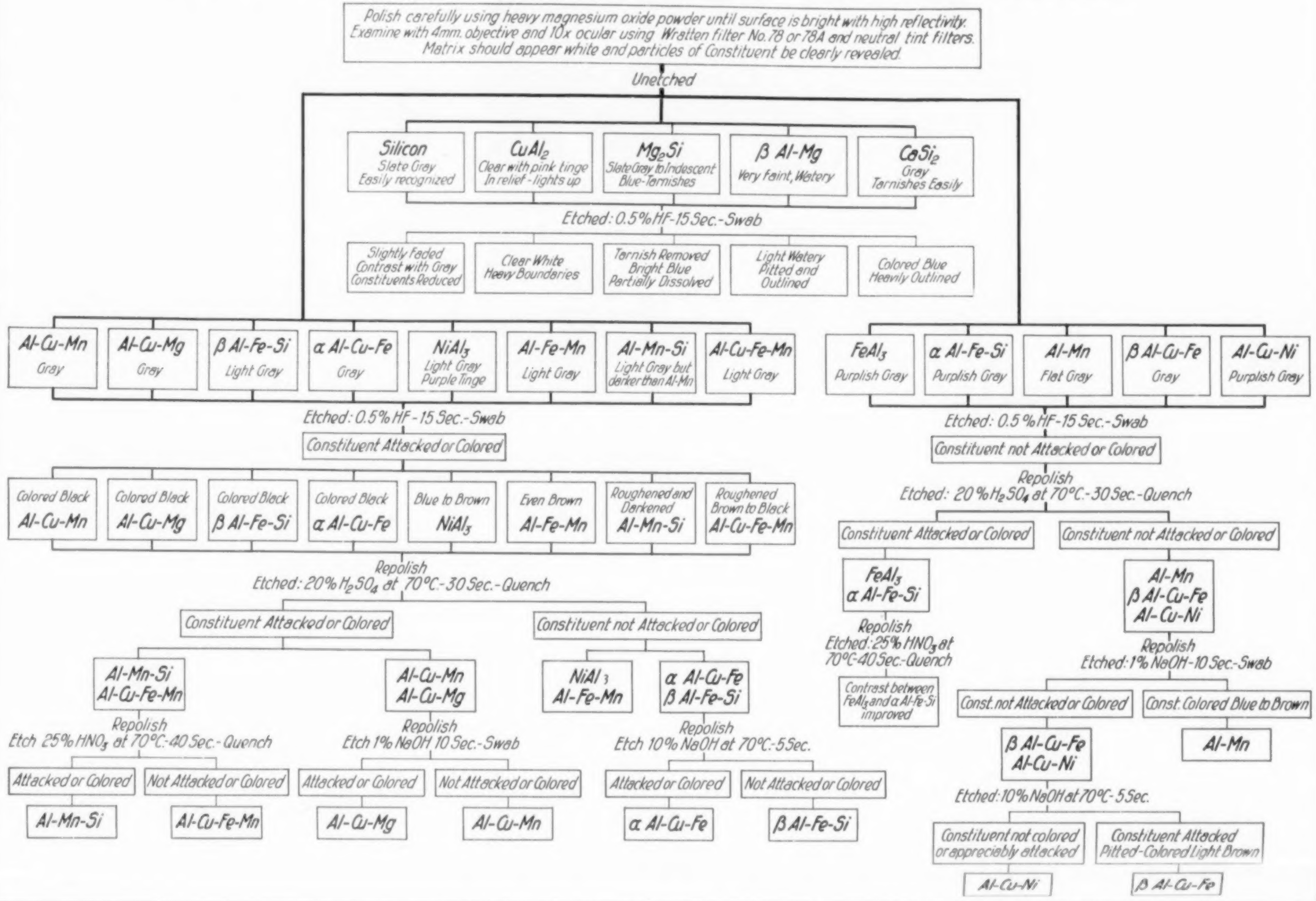
By J. C. Fox
Chief Metallurgist
Doehler Die Casting Co., Toledo, Ohio

AS AN undoubted trend, the die casting process is increasing in importance among contemporary metal fabricating processes, contributing greatly to the economical production of metal parts in quantity. Furthermore, the die casting industry is steadily moving forward, under a definite program of research and development on metal alloys, die materials and casting mechanisms.

Zinc alloy die castings continue to expand in size, quantity consumed, and diversity of application. Their moderate cost, good physical properties, and adaptability to a wide range of

Identification of Constituents in Commercial Aluminum Alloys

By F. Keller and G. W. Wilcox, Aluminum Research Laboratories (After Dix and Keith, with additions)



shapes and sizes are the main reasons for their popularity. Their only limitations are in certain structural applications involving use beyond 200° F., and in other cases where the very maximum in dimensional stability and corrosion resistance is necessary.

The automotive industry takes about 50% of the total produced. It is interesting to note that ten years ago the ratio was about the same as today, but the total amount of die castings produced in 1938 will be about four times that of 1928. This shows the greater use of zinc for applications other than automotive.

Much is being done in the development of better casting machines, mainly in the direction of size, both large and small, in speed and in safety of operation. Soundness of castings is being improved by controlled die temperatures which are being maintained by properly balancing the speed of operation against the devices for cooling the dies. As yet no limitations have been reached as to how large or how small a casting can be produced economically. Large automatic machines are available to handle a radiator grille or auto-body molding, and correspondingly small, fast machines for tiny castings like zipper teeth.

Constant research in the direction of chemical composition has resulted in a third zinc alloy, No. XXV, to the two alloys standardized in 1934 under the guidance of Committee B-6 of the American Society for Testing Materials. There appears to be a strong tendency toward the elimination of the old A.S.T.M. XXI alloy, which contains 3% copper, in favor of the more stable alloys A.S.T.M. XXIII (zinc-aluminum-magnesium) and the new XXV (zinc-aluminum-magnesium with 1% copper).

New and better finishes for die castings are constantly being brought out.

Aluminum alloy die castings have been little changed in composition in the last decade. However, during the last couple of years the development of a new die casting technique offers tremendous possibilities. In the new method of casting, the alloy can be handled with less possibility for gas absorption, less oxidation, and with no iron pick-up. This is responsible for better physical properties than were previously available, the castings being uniform in quality, structurally sound and dense. The same dimensional accuracy and appearance can be had as with the old method. If the highest electrical conductivity of aluminum is required, the purest aluminum metal can be cast by this new process. Its essential difference is in the much higher pressures utilized.

Magnesium alloy die castings are possibly of most interest to the designing engineer. Their development and expansion is an outstanding feature in recent aircraft improvements. As the properties of magnesium and its alloys become more familiar, greater use will be made of them in other industries. Ultra-lightness is their most outstanding characteristic. The mass-strength ratios of magnesium alloys to other metals show that they can be used for many structural parts where lightness will result in higher working speeds at lower operating costs. The saving is one third of the weight where aluminum is replaced and three quarters of the weight where it replaces steel.

Magnesium alloys can be machined faster and better than any other metal known to the writer. The die castings possess good physical properties and their stability in service has been demonstrated in a large number of varied applications.

Brass die castings have steadily increased in field of applications. The salient qualities of high strength, hardness and corrosion resistance fit the brasses into uses where die castings of other metals are unsuited. The automotive industry, for instance, has found a number of applications, and unquestionably this use will expand in time.

Brass die casting alloys are capable of a tensile strength of 100,000 psi. and Brinell hardness up to 200. These properties guarantee many future uses.

Considerable research is being directed toward bettering the present die steels. This alone is standing in the way of further development of this process in the higher melting alloys — especially brass die castings. Longer life for dies will greatly aid in reducing present production costs in such items.

Aluminum and Its Alloys

By Junius D. Edwards
Aluminum Research Laboratories
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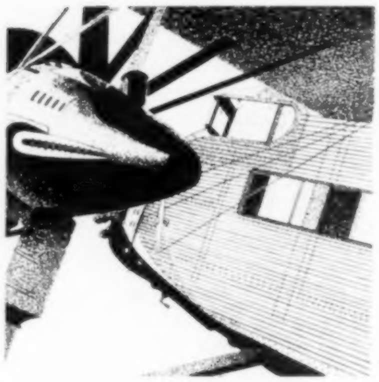
PROGRESS during the year 1938 has been along the line of commercial development and new applications rather than in the introduction of new alloys. Among the wrought alloys, 2S and 3S (commercially pure and 1¼% manganese, respectively) still supply the bulk

of wrought aluminum products. Of the newer heat treatable alloys, 53S and 24S are meeting a wide range of requirements. Alloy 53S, of the magnesium-silicide type, is continually finding new applications especially in marine work, to which its excellent resistance to corrosion particularly adapts it. 23S, a high strength alloy with an ultimate strength of about 68,000 psi., has become standard in the aircraft industry for strong alloy sheet, tubing and extruded shapes. It has been described in METAL PROGRESS in January 1937, wherein it is noted that it differs in composition from the well-known 17S (4% Cu, 0.5% Mn and 0.5% Mg) by having slightly more copper and three times the magnesium. Alclad 24S-T is being widely used bare, without paint or other protection than its integral coating of pure aluminum. Aircraft forgings, described in another section of this magazine, use 14S and 25S (4.5% Cu, 0.8% Mn, 0.8% Si).



In the laboratory, the use of X-ray, metallographic, dilatometric and electrical conductivity methods is revealing more and more about the mechansim of precipitation hardening and other fundamental phenomena, which should eventually lead to improvements in alloying and metal working technique. Correlated with investigations of the internal structure of metals are fundamental studies of the mechanism of corrosion. For example, the attack on aluminum in salt solutions has been shown to be entirely electrochemical in nature, and quantitative studies of corrosion phenomena will eventually lead to better methods of protection. Much careful study is also being given to the fundamental actions occurring during the early stages of hardening (precipitation hardening at room or slightly elevated temperatures).

Aluminum reflectors electrolytically brightened and anodically coated have received the approval of illuminating engineers. There is continued active development of methods of finishing aluminum; the "alumilite" process of oxide coating was applied to more than 20,000,000 lb. of aluminum in 1937.

The engineer now has available, in new and revised editions, two useful books on aluminum. The first of these, "Alcoa Aluminum and Its Alloys", gives basic information on the properties of all of the commercial wrought and cast alloys. The second, "Structural Aluminum Handbook", is limited to those alloys that are produced as larger plates and shapes intended for general structural purposes. It not only serves as a "shape" book, but also contains chapters on the selection of working stresses and design of aluminum alloy structures. Of special interest is the unusually complete treatment of the stability of thin sections, a problem of great importance in modern light weight structural designs.

Zinc and Its Alloys

By W. M. Peirce
Chief, Research Division, New Jersey Zinc Co.
Palmerton, Pa.

PRODUCTION METALLURGY of zinc has undergone no changes of particular significance to the consumer during the past year. Zinc of 99.99+% purity is available in adequate quantity from three producers. The electrolytic process and the redistillation process are both well established. Viewed in retrospect it has become clear that the market conditions of a year ago were more the result of excited buying than the result of a shortage of metal for actual consumption.

The past year has given added evidence that Special High Grade zinc (99.99+% pure) has firmly entrenched itself in a number of fields. In fact, economic stringency has resulted in surprisingly few efforts to substitute the cheaper, less pure grades and these efforts have usually been abortive. Die casting continues to be the major outlet for this grade of zinc, and depressed business conditions appear to have stimulated the increasingly diversified use of zinc alloy die castings.

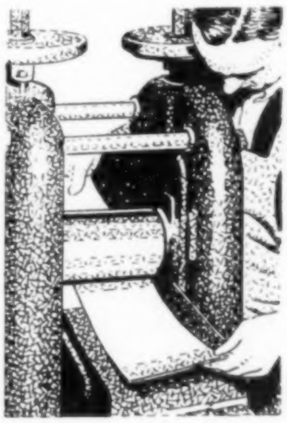
Entrance in the fields of business machines and household appliances has been particularly important. Good examples are, in the one case, a time clock where the use of a substantial proportion of zinc alloy die castings has permitted a large reduction in the total number of parts and, in the other, a lawn mower in which cast iron has been replaced by lighter zinc alloy die castings.

Zinc coating of steel, the major use of zinc, has been the subject of much attention. Here the inevitable effects of the tests conducted by the American Society for Testing Materials, and the educational program of the American Zinc Institute (the latter based to a great extent on actual service experience) are becoming increasingly felt.

It is being brought home to all consumers that zinc coatings, in the wide field where they are properly applicable, offer the best means of protecting steel against rust and that the degree of this protection depends upon the thickness of the coating. This has, of course, been reflected by a demand for more heavily coated galvanized products which the producers are actively attempting to meet.

The development of new zinc alloys offers little on which to comment. A zinc die casting alloy already well known and established in the trade has been added to the A.S.T.M. specifications. This alloy, designated as Alloy XXV, contains approximately 4% aluminum, 0.04% magnesium, and 1% copper, and is intermediate in properties between the older Alloys XXI and XXIII which contain 3% and zero per cent copper, respectively, and are substantially the same in other components. All three alloys are, of course, based on 99.99+% zinc. Alloy XXV combines most of the strength and hardness of the higher copper alloy with most of the freedom from age hardening of the low copper alloy.

Use of the 1% copper-zinc alloy in the rolled form has gradually increased, and this composition is now a recognized and important grade of rolled zinc. Much activity has been reported abroad particularly in the field of rolled and extruded zinc alloys. While it is too early to venture an opinion as to whether any of these will become important in this country, it may be pointed out that a good deal of work has been done in the past with alloys of the types which have been reported from abroad, yet they have not so far found a market here. Abroad the desire to conserve other materials apparently offsets shortcomings in these alloys which have forestalled their use in the United States. Changing economic conditions in our own country or improved formulation of some of these alloys may change this situation.



The Minor Metals

By E. E. Schumacher
Bell Telephone Laboratories, New York City

IT IS DIFFICULT, these days, to differentiate between the "major" and the "minor" metals, since many of those placed in the latter class may tomorrow assume marked technical importance. Even so, the field is so wide that only the merest mention can be made in the available space of some technical developments discussed in the engineering and scientific reviews during the past four or five years.

Calcium has achieved at least three noteworthy uses. First, as a purifier and scavenger it is a common deoxidizer for copper and for copper-tin bronzes. Second, it is alloyed with lead for cable sheath and storage battery grids. Third, additions of calcium are reported to improve the fluidity of liquid steel.

Manganese is distinctly not a minor metal to the steel master. Newsworthy is the development of process for producing high grade manganese metal, reported by the Bureau of Mines, and the possibility of new alloys from its use. Manganese is now used in non-ferrous alloys to produce greater strengths, to give resistance to corrosion under some conditions and to increase the workability.

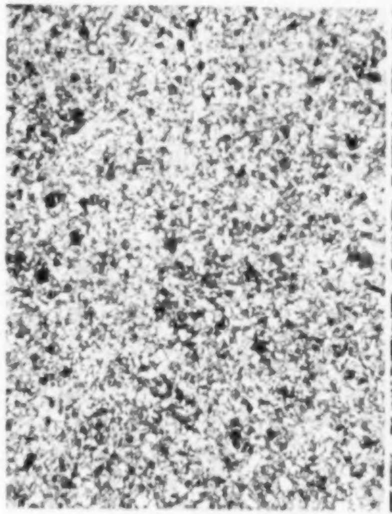
Titanium carbide has been used successfully with tungsten carbide to improve the cutting properties of tools at elevated temperatures.

Titanium metal in copper-beryllium alloys is reported to stabilize the hardness at temperatures above those ordinarily encountered by the binary alloy. Age hardening compositions of copper and titanium are also reported to have useful possibilities. Titanium present in some complex alloys such as konel produces age hardening. Other compositions with desirable properties will also undoubtedly be developed.

Zirconium — Fairly high purity metal has been produced in powder form and ductile zirconium has been commercially manufactured in many shapes. It has a high corrosion resistance, and the fabricated articles should have a fairly important industrial outlet. One use has been as a material for the manufacture of rayon spinnerets. Like titanium, zirconium has been

Standards for Estimating Grain Size (Non-Ferrous)

American Society for Testing Materials Standard E2-36 (copyrighted) for annealed materials such as brass, bronze, nickel silver
Actual diameter of average grain is noted; Magnification of micros: 75×



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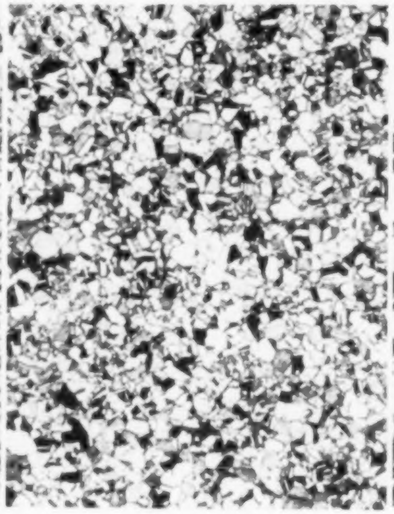

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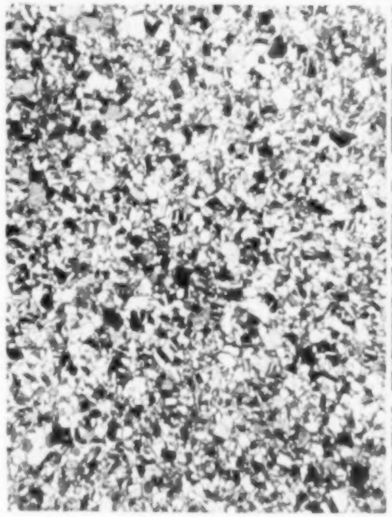

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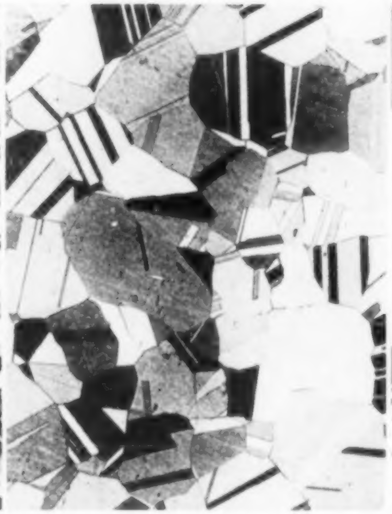

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found to increase the high temperature stability of copper-beryllium alloys. A copper-zirconium age hardening alloy has been developed, and others of similar type may be expected.

Additional uses might be expected for zirconium as a scavenger for oxygen, nitrogen, and sulphur in steel making where economic considerations do not preclude its use.

Tantalum — Development of methods for fabricating and welding tantalum have extended its use in somewhat the same fields of corrosion resistance as zirconium. Addition of tantalum carbide to tungsten carbide gives a better cutting material at high temperatures.

Indium — Improvement of corrosion resistance of cadmium bearing metals has been effected by the use of indium in the alloy. Although a rare metal, assurance has been given that an adequate supply can be furnished. It is used also as constituent of precious metal alloys for jewelry, where it is reported to impart tarnish resistance. As a constituent in dental castings and amalgams, indium gives superior compressive strength, satisfactory flowing and setting properties, and resistance to tarnish. It is reported that a high concentration of indium is needed to inhibit tarnish of silver effectively, and a process has been developed for coating silver with a thin layer of indium which is diffused into the silver by appropriate heat treatment to form a surface layer of silver containing a high concentration of indium.

Rhodium plating of silverware, to prevent tarnish, has also been commercially exploited.

Beryllium — It has been reported recently that extreme surface hardness can be imparted to iron and nickel by cementation with beryllium. Such a process should have considerable commercial possibilities.

Tellurium — The use of silver-tellurium alloys having a negative temperature coefficient of electrical resistance has been reported, and is said to be useful for temperature compensation for control instruments.

Silver—A summary of the industrial uses of silver was published in METAL PROGRESS in July 1937 and widely quoted. An extensive research into such matters is now under way, financed by the important American producers. Possibilities of commercial importance exist in the further use of silver as electrical contacts, bearings, coatings and alloys with base metals. As pointed out in the leading article of this section, interesting alloys made from silver powders are also available.

Heat Treatment
of Non-Ferrous Alloys in
Controlled Atmospheres

By Paul E. Petersen
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Waterbury, Conn.

RECENT YEARS have shown a rapidly growing application of controlled carbonaceous atmospheres (in distinction to atmospheres of water vapor) to the heat treatment of many non-ferrous alloys.

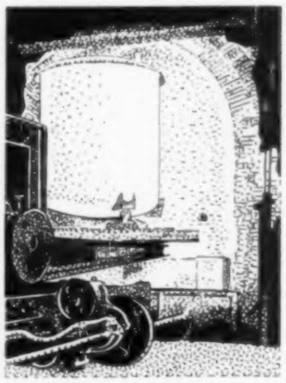
The many factors which have brought about this trend will no doubt demand a wider application in the future. Exacting specifications by the purchaser have necessitated improvements in finish on all products, and controlled atmospheres are decided aids in meeting these demands. Economies effected by such items in processing as elimination or reduction of pickling and metal loss by oxidation, increased die, tool or roll life, reduction of rejections caused by improper surface finish, have done much to justify their use. The continual development of new alloys, many of which cannot be annealed and readily pickled by the old methods, has necessitated controlled atmospheres without which their manufacture would be impractical.

Generally speaking, the process consists of heating the metal to a temperature necessary to give the desired physical characteristics, and subsequently cooling — both operations in an accurately controlled atmosphere to prevent or minimize surface oxidation and discoloration. This may be termed "bright annealing" where material is actually as bright or brighter than before annealing, or it may be termed "clean annealing" where oxidation is minimized.

Controlled atmosphere heat treatment involves many factors other than atmosphere, all important. Briefly, these factors are source of atmosphere, actual atmosphere composition, composition of alloy being treated, surface condition of material being treated, temperature of treatment, time of treatment, and (very important) a furnace that will coordinate these various factors.

Sources of atmosphere are many and varied, some expensive and some relatively cheap. Manufactured gas, natural gas, producer gas, propane, butane, ammonia, charcoal, and water are all potential sources. Some of these such as manufactured gas, natural gas,

propane, and butane may be used directly as atmosphere on some alloys, if sulphur compounds have been removed, but their use in this way is expensive and hazardous. These same fuels, when correctly proportioned with air and combusted in special generators for the purpose, can be made to yield an atmosphere with small amounts of carbon monoxide and hydrogen, and larger amounts of carbon dioxide and nitrogen satisfactory for many alloys and decidedly less expensive than the raw fuels. The composition can be readily and closely controlled to give a fairly wide spread in ratios of these gases. Moisture may be removed if necessary by refrigeration, silica gel, or activated alumina, and carbon dioxide by special absorbing compounds. However, where carbon dioxide and water vapor are objectionable, ammonia usually is very satisfactory, which at high temperatures and by means of a catalyst is cracked to yield an atmosphere of 25% nitrogen and 75% hydrogen.



This may be partially combusted to give an atmosphere gas lower in hydrogen and higher in nitrogen, which then has to be dried to remove moisture from combustion of the hydrogen. In some instances charcoal has been combusted to yield an atmosphere of carbon monoxide, carbon dioxide, and nitrogen satisfactory for copper annealing.

Copper is perhaps one of the easiest metals to bright anneal, the chief atmosphere requirement for both heating and cooling being absence of oxygen and sulphide gases. Steam was one of the earliest atmospheres for copper annealing. Most products of combustion, when maintained on the reducing side, can be made to bright anneal copper by proper application. Cupro-nickels and high copper alloys of tin are also easily bright annealed in controlled products of combustion. Brasses, due to the volatility of the zinc at annealing temperatures and to the fact that both carbon dioxide and water vapor oxidize the zinc, are less easily bright annealed. Brasses and some of the special alloys of copper containing silicon, manganese or beryllium offer special problems, and cannot utilize the ordinary products of combustion without special treatment for removing both carbon dioxide and water vapor. For these sensitive alloys, cracked ammonia is usually the simplest atmosphere to use and gives the best results. Raw hydrocarbon gases are free of carbon dioxide and water vapor and can be used for these sensitive alloys, but they offer special troubles in furnace design due to soot formation.

A vital factor often given insufficient consideration is the condition of the surface of the metal going to the furnace. Lubricants of various kinds, particularly some soaps, and various roll oils, cause discolored metal when the atmosphere otherwise would be perfect. Controlled atmospheres are usually non-oxidizing so that lubricants will not burn off, but must distill; any non-volatile lubricant, therefore, usually results in some staining. Dependent on furnace design and travel of gases, a small amount of soap or lubricant on only a small portion of a charge may contaminate and discolor the whole. Also, it is possible to contaminate the brickwork or alloy in a furnace to such an extent that prolonged purging may be necessary before clean annealed work can again be obtained.

Furnace design is one of the most important considerations, and the varied types and designs are almost as numerous as the articles that are treated. The furnace must maintain the atmosphere through both heating and cooling, and must exclude all air infiltration and atmosphere contamination, and must do this with a minimum amount of atmosphere consumption. Generalizing, the simpler the alloy, the simpler the atmosphere and the simpler the furnace. Copper, for example, can utilize products of combustion in a bell type furnace and be annealed perfectly bright. The special alloys mentioned above require atmospheres free of carbon dioxide and bone dry, and usually require very short time cycles, necessitating the use of continuous furnaces, decidedly more complicated in construction than simple batch furnaces.

Developments to date indicate that it is possible to bright anneal practically any commercial non-ferrous alloy by proper control of atmosphere and furnace design, and economies are being effected which justify their use. As these benefits are more fully appreciated there will no doubt be a much wider application of controlled atmosphere to heat treatment of the non-ferrous alloys.